A MANUAL

OF

THE GEOLOGY OF INDIA.

CHIEFLY COMPILED FROM THE OBSERVATIONS OF THE GEOLOGICAL SURVEY.

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PART I: PENINSULAR AREA.

PREFACE.

THE want of a general account of Indian Geology has been felt for some years. The regular Geological Survey of India may be considered to have commenced in 1851; and but few of those who took part in the work during the earlier years now remain in the Service. It is desirable, before all the older Members of the Survey pass away, that some record of the early observations, many of which are unpublished, should be rescued from oblivion, for the benefit of future explorers. The published Memoirs and Records of the Survey, moreover, have now become too numerous and bulky for general use; and it is difficult for any one, without much study, to gather the more important observations on the geology of the country from amidst the mass of local details. Many papers on Indian Geology are also scattered through various Indian and European periodicals. As a guide to all who have occasion to acquire a knowledge of Indian Geology, or who desire information from a love of the science, some compendium of the observations hitherto collected has become absolutely necessary; and the present Manual has been drawn up, by direction of the Government of India, to supply the deficiency.

It was originally desired by the Government that this work should be prepared by the late Dr. Oldham, or that the compilation should have the advantage of his supervision. As Dr. Oldham was the first Superintendent of the Survey, and

remained at the head of the Department from its commencement in 1851 to 1876, he would, unquestionably, have been admirably qualified to carry out the work; and it was his own desire to do so, as the completion of his labours in India. Failing health, however, and the pressure of other duties, prevented him from even commencing the task; and when, at length, he was unable any longer to remain in the country, the duty of preparing a Summary of Indian Geology was left to his successor. At this time, the only preparation that had been made for the work was the partial compilation of a general Geological Map of the Peninsula.

The double authorship was not entirely a matter of choice; although undertaken, and carried out, most willingly by both the writers. Both have been engaged in the work of the Survey almost from the commencement; and as each has, in the course of his service, examined very large areas of the country, the combination secures the description and discussion, from personal knowledge, of a much larger portion of India. At the same time, the advantages of wider experience and thought may not be found an adequate compensation for want of uniformity and occasional discrepancies—the natural results of divided authorship. To secure, so far as possible, the responsibility of each author for the facts and opinions stated, the initials of each are affixed in the Table of Contents to the chapters contributed by him. Every such chapter has been read and revised by the other writer; but the alterations have in no case been of more than trivial importance; so that each chapter may be practically taken as an individual contribution. The number of subjects is so large, and the connexion between them, in many cases, so slight, that the lack of uniformity will not, it is hoped, seriously detract from the usefulness of the Manual.

In addition to the subjects discussed in the present work, it was, at first, proposed to add an account of the Economical Geology, and to treat in a special chapter of the known Mineral Resources of India. But the length to which the Manual has already extended, has rendered it advisable to

postpone this very important subject, and to reserve it for a separate volume.

Although many of the details in the work now issued have not previously been published, and although the discussion of the observations involves several new deductions and suggestions, the book is, in the main, a compilation; and it is quite possible that, especially in treating of areas and formations of which the authors have no personal knowledge, full justice has not always been done to the views of original observers. It has, in several instances, been thought more important to point out possible causes of error, than to endorse opinions which, although very possibly correct, are not sufficiently supported by published data to be accepted as conclusive. In all such cases full references to previous publications have been furnished; and an examination of the details given in the latter will, it is hoped, serve to correct any errors of interpretation on the part of the authors of the present work.

The numerous and large areas left blank in the annexed Map shew, at once, how far the present publication falls short of completeness, and how imperfectly the promise implied in the title is fulfilled. A note upon the Map further explains, that large portions of it have been coloured from very imperfect information, from sketch surveys or rapid traverses, affording no sufficient opportunity for a proper study of the formations. It had, however, become imperative, as a duty to the public, for reasons already mentioned, to bring together a summary of the work accomplished since the commencement of the Survey; and it was equally essential for the Survey itself, that some general record of the results obtained up to date should be compiled. These objects could only be attained by attempting a general Map and Review of the Geology of India; but the reader must not forget that the present attempt is more of the nature of a progress report than of a finished work.

The Map, it is feared, will be found defective in several other respects. Under the circumstances, it was impossible

to prepare a special reduction of the topography; and, amongst the Maps of India available in the Surveyor General's Office, there was, practically, no choice but to accept that on the scale of 64 miles to the inch, then well advanced towards completion, as a basis for the geological details. The scale is inconveniently small for all parts of the country that have been geologically mapped in any detail, and the mountain ranges have not been inserted; so that many features discussed in the text are not indicated. But the most serious drawback is in the names of places. Many towns of importance are omitted, owing to the small scale; and other names of interest, for purposes of geological description, such as those of fossil-localities, or of villages near important sections, are wanting. Nor is this all. The spelling of Oriental names is a well-known cause of perplexity; and the confusion has been increased by the unfortunate circumstance that, while one system has been adopted by the Great Trigonometrical Survey, and employed in all the maps, including those of the detailed Topographical Surveys, issued by the Department, an entirely distinct system has been employed by the Revenue Survey, by whom the maps of all the best known parts of the country have been prepared. Under the first system, each letter in the Indian language is represented by a corresponding letter in the Roman character; diacritical marks and accents being employed to distinguish such consonants or vowels in the latter as are required to represent two or more sounds, and the Italian or German sounds of the vowels being used, instead of the English. Under the second system, an attempt is made to represent the original sound by English spelling; double vowels being largely used, but no diacritical marks. The imperfection of the latter plan is manifest; because, in the first place, the sounds, of the vowels especially, in English, are variable, and incapable, in many cases, of representing those of Oriental languages; and secondly, the representation of the true names by supposed equivalents is arbitrary, depending chiefly on the ear, often very imperfectly trained, of the

transcriber. When maps of large areas, as in the present case, are compiled, the mixture of names, spelt according to two different systems, is inevitable. The attempt at a general revision of the nomenclature, however desirable, would have involved serious delay.

Of late, the Government has adopted a compromise in the question of spelling, and lists of the principal places in each province have been issued; the familiar and well-known names being spelt in the manner that has become customary by usage, whilst transliteration is employed in all other cases, with the exception that no diacritical marks are used for consonants. This system is obligatory for all official publications; and it has, consequently, been adopted in the present work. In some cases, however, the lists for particular provinces have not been published in time to be available; and in the following pages it is not unfrequently necessary to mention places not contained in the lists, and the proper vernacular pronunciation of which is unknown to the writers. In such cases, an attempt has been made to spell the name according to the recognised system; but it is only fair to warn the reader that no dependence can be placed on many names of places, especially upon those in the south of India, when taken from old maps.

In the preparation of the Map, a large share has been taken by various Officers of the Geological Survey, all of whom have contributed. The colouring and printing have been carried out at the Surveyor General's Office, under the superintendence of Captain Riddell, R.E., to whom the authors beg to express their obligations for the labour he has given to the work, and for the assistance he has afforded to them personally.

In the plates of fossil plants and animals at the end of the work some of the most common and characteristic forms of organic remains found in India are represented. The plants have been selected and arranged by Dr. Feistmantel, and the tertiary Mammalia by Mr. Lydekker. All the plates are lithographed by Mr. Schaumburg, whose work

will answer for itself. The majority of the figures are from original drawings, or from the "Palæontologia Indica;" the remainder are copied from other works; but these copies have, in many cases, been compared with specimens.

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INTRODUCTION.

Nature of present work — Limits — Physical geography of India — Sub-division into Peninsular and Extra-Peninsular areas — Rivers of Peninsula — Mountain ranges of Peninsula — Mountain ranges of Extra-Peninsular area — Sind and Western Punjab — Himalaya — Ranges and rivers of Burma, &c. — Geological formations in general — List of Peninsular formations — List of Extra-Peninsular formations — Summary of geology — Metamorphic rocks — Transition rocks — Vindhyan series — Probable conditions of deposit — Palaeozoic rocks of Salt Range — Oldest rocks of Northern Punjab, Kashmir, &c. — Oldest rocks of Himalaya — Gondwána system — Physical geography of Gondwána period — Relations of Gondwána flora and fauna — Climate of Gondwána epoch — Jurassic marine rocks — Cretaceous marine rocks — Distribution of cretaceous land — Deccan traps — High-level laterite — Tertiary coasts of Peninsula — Extra-Peninsular mesozoic rocks — Tertiary rocks — Distribution of eocene land — Later tertiary beds — Siwalik fauna — Origin of Himalayas — Origin of Indo-Gangetic plain — Distribution of recent fauna — Ethiopian affinities of Oriental mammals — Ethiopian affinities of Indian mammals — Affinities of land shells — Survival of older types in the Indian area — Glacial epoch — Sub-recent changes of level — Previous summaries of Indian geology: Calder, 1833 — Newbold, 1844 — Carter, 1854 — Greenough, 1854 — Later sketches — List of European formations — Classification of animal kingdom.

Nature of present work.—The present, although by no means the first general description of the Geology of India, differs from most previous works on the subject in the extent of the area described, and from all in the amount of information in the hands of the writers. The greater number of the papers hitherto published on the Geology of the British possessions in India and the neighbouring countries have dealt only with portions of the territory; and, since the establishment of a Geological Survey by the Government of India, no opportunity has hitherto been afforded of bringing much scattered information, procured by the Officers of the Survey, but, on account of incompleteness, or for other reasons, hitherto unpublished, into connexion with the published data distributed throughout the Memoirs and Records of the Survey, and the Journals of various Scientific Societies. The urgent need for a general exposition of the present state of Indian Geology has led to the present attempt to combine the observations of all Members of the Geological Survey, past and present, with the information collected by other Geologists, and to give a general view of the existing state of knowledge on the subject.

Limits.—The limits of the country described in the present work coincide in general with those of the territory under British rule or protection: a few notes will occasionally be added on the geological features of countries beyond the boundary, wherever information is available; but this is rarely the case. There is, in general, far more reason for us to deplore the ignorance still existing of tracts in the British dominions, than to congratulate ourselves on our acquaintance with foreign territory beyond the limits of the "red line."

Physical geography of India.—Before proceeding to any geological details, it may not be out of place to glance briefly at the physical features of the region under consideration. With the general outline of the British possessions in India and Burma all are acquainted. The great triangular promontory, with the island of Ceylon south-east of its extremity, to the west of the Bay of Bengal, and the long narrow belt of country along the shore of Burma, with a broader expanse in the Irawadi valley to the southward, and the long narrow plain of the Brahmaputra to the northward, east of the Bay; the broad and high mountain chain of the Himalayas, with the loftiest peaks in the world dotted along its snowy range, stretching in a vast convex curve from west to east along the northern boundary, and forming the barrier between the tropical plains of India and the cold and barren plateaus of Tibet: all these are familiar to every one. But there are a few other peculiarities of the region intimately connected with its geological structure, and deserving of a brief notice; and as the nomenclature of the Indian mountain ranges is by no means definitely settled, it is necessary to explain terms which must frequently be used in the ensuing pages.

Sub-division into Peninsular and Extra-Peninsular areas.—The first of the peculiarities to be noticed is the great alluvial low-level plain of Northern India, watered by the Ganges and Indus and their tributaries; and hence known as the Indo-Gangetic plain. This is an immense expanse of flat country stretching from sea to sea, entirely composed of alluvial deposits of very late geological age, and dividing the hilly ground of the Peninsula from the various mountain and hill ranges of Sind, the Punjab, the Himalayas, Assam, and Burma. It will presently be shewn that this sub-division is not merely geographical, but that a trenchant distinction exists between the rocks of the Indian Peninsula and those of the *Extra-Peninsular area*, as the territories divided from the *Peninsular area* by the Indo-Gangetic plain may be termed collectively. The geological history of these regions is widely different; and even in the characters of the surface there is a marked contrast, due

to the great effects produced by disturbance in late geological times throughout the Extra-Peninsular region—an effect culminating in the elevation of the great Himalayan chain;—whilst in the Peninsula there appears to have been singularly little contortion or alteration of the strata after a very early period. The Vindhyans of Bundelkhand and Central India are certainly not newer than lower palæozoic; yet they are nearly horizontal throughout the greater part of their area; and they are far less tilted and folded than the pliocene Siwaliks along the base of the Himalayas, and of the Punjab and Sind mountains, on the opposite side of the Indo-Gangetic plain.

The first step towards a comprehension of Indian geology is this sub-division of the country into three distinct regions—Peninsular India, the Extra-Peninsular area, and the great Indo-Gangetic alluvial plain separating the two. The plain requires no further description at present; its peculiar features, many of them of singular geological interest, will be found described in the chapters relating to post-tertiary and recent formations. The physical geography of the other regions is less simple. The Peninsula is the most important portion of the British territories in Southern Asia; it comprises the greater part of India proper, and its geology has received much more attention than has that of the neighbouring countries; consequently it requires to be first noticed.

Rivers of Peninsula.—Some of the main features of India and the neighbouring countries are represented in the accompanying sketch map, on which only the principal rivers and the mountain ranges are marked. The rivers of the Peninsula are seen at a glance to comprise two well-marked groups, irrespective of the streams flowing to the Ganges: these groups are—first, the rivers running to the westward, and terminating in the Arabian Sea, the Narbada (Nerbudda), and Tapti (Taptee) being alone of sufficient importance to be noted; secondly, the rivers running to the Bay of Bengal, the principal of which are the Mahánadi (Mahanuddy), Godávari (Godavery or Godavri), Krishna (Kistna), and Cauvery (Cavery or Kaveri). It should further be observed that the only large streams running westward drain the northern portion of the Peninsula, and that, except in a narrow strip of country close to the western or Malabar coast, all the drainage south of the Tapti valley, even from the summits of the hills within sight of the western sea, runs eastward to the Bay of Bengal.

Mountain ranges of Peninsula.—The nomenclature of Indian mountain ranges is still a difficulty, it being a rare exception that any definite term is applied to a mountain chain, throughout its extent, by the people of the country. In many parts of India, peaks and passes

have names, but the ranges have none; and even if names exist, their application is not unfrequently vague. Thus the ancient name of "Vindhya," applied to the hills separating Hindustan proper or the Gangetic country from the Deccan (Dakhin or south) has now, by common consent, been restricted to the hills north of the Narbada; but it appears almost certain that the term originally applied also to the ranges now known as Sátpura, south of the river; and it is very probable that the latter hills were more especially indicated by the term "Vindhya" than the former. The term "Sátpura," again, was of very indefinite application, and probably included other ranges, besides that to which it is now restricted. The names here applied are those employed by the latest writers on Indian geography; but some of them are by no means generally adopted on maps.

The most important mountain ranges of the Peninsula are the *Sahyádri*, or Western Ghâts, running along the western coast, from the Tapti river to Cape Comorin, at the southern extremity of the Peninsula; the *Sátpura*, running east and west, on the south side of the Narbada valley, and dividing it from the drainage areas of the Tapti to the westward, and the Godávari to the eastward; and the *Arvali* (Aravalli or Aravally), striking nearly south-west to north-east, in Rájputána. The so-called *Vindhyan* range, north of the Narbada, and the eastern continuation of the same north of the Son valley, known as the Kymor range, are merely the southern scarps of the Vindhyan plateau comprising Indore, Bhopal, Bundelkhand, &c. The plateaus of Hazáribágh and Chutia Nágpúr (Chota Nagpore) in South-Western Bengal appear to form a continuation to the eastward of the Sátpura range; but there is no real connexion between these elevations and the Sátpura chain; they are formed of different rocks, and there is no similarity in the geological history of the two areas, so far as it is known. In many maps a range of mountains is shewn along the eastern coast of the Peninsula, and called the Eastern Ghâts. This chain, as a whole, has no existence, but is composed, to the southward, of the eastern scarp of the Mysore plateau, and to the northward of the south-eastern scarp of the Bastar-Jaipur plateau, north-west of Vizagapatam, and of several short isolated ridges of metamorphic rocks, separated from each other by broad plains, and having in reality but little connexion with each other. There are also several minor ranges, such as the Rájmahál hills in Western Bengal, the Indhyádri between the Tapti and Godávari, the Nallamalé (Nullamullay) near Kadapah, north-west of Madras, and the little metamorphic plateaus, such as the Shivarais (Shevroys), Pachamalé, Kolamalé, &c., scattered over the low country of the Carnatic, south-west of Madras.

The peculiarity of all the main dividing ranges of India is, that they are merely plateaus, or portions of plateaus, that have escaped denudation. There is not throughout the length and breadth of the Peninsula, with the possible exception of the Arvali, a single great range of mountains that coincides with a definite axis of elevation ; not one, with the exception quoted, is along an anticlinal or synclinal ridge. Peninsular India is, in fact, a table-land, worn away by subaërial denudation, and perhaps to a minor extent, on its margins, by the sea ; and the mountain chains are merely the dividing lines left undenuded between different drainage areas. The Sahyádri range, the most important of all, consists to the northward of horizontal, or nearly horizontal strata, of basalt and similar rocks, cut into a steep scarp on the western side by denudation, and similarly eroded, though less abruptly, to the eastward. The highest summits, such as Mahábleshwar (4,540 feet), are perfectly flat-topped, and are clearly undenuded remnants of a great elevated plain. South of about 16° north latitude, the horizontal igneous rocks disappear, and the range is composed of ancient metamorphic strata ; and here there is in some places a distinct connexion between the strike of the foliation and the direction of the hills ; but still the connexion is only local ; and the dividing range consists either of the western scarp of the Mysore plateau, or of isolated hill groups, owing their form apparently to denudation. Where the rocks are so ancient as those are that form all the southern portion of the Sahyádri, it is almost impossible to say how far the original direction of the rang is due to axes of disturbance ; but the fact that all the principal elevations, such as the Nilgiris (Neilgherries), Palnés (Pulneys), &c., some peaks on which rise to over 8,000 feet, are plateaus and not ridges, tends to shew that denudation has played the principal share in determining their contour.

The southern portion of the Sahyádri range is entirely separated from the remainder by a broad gap, through which the railway from Madras to Beypúr passes west of Coimbatúr. The Anamalé, Palné, (Pulney), and Travancore hills south of this gap, and the Shivarai (Shevroy) and many other hill groups scattered over the Carnatic, may be remnants of a table-land once united to the Mysore plateau, but separated from it and from each other by ancient marine denudation. Except the peculiar form of the hills, there is but little in favour of this view ; but, on the other hand, there is nothing to indicate that the hill groups of the Carnatic and Travancore are original elevations.

The whole of the Western Sátpuras, from their western termination in the Rájpipla hills to Asirgarh, consist of basaltic traps, like the Sahyádri, the bedding being, it is true, not horizontal ; but the dips are low and

irregular, and have no marked connexion with the direction of the range. The Central Sátpuras, comprising the Pachmarhi or Mahádeva hills, from the gap in the range at Asirgarh to near Narsingpur, are composed chiefly of horizontal, or nearly horizontal, traps, but partly of sandstones and of metamorphic rocks; and there is here again, as in the Southern Sahyádri, some connexion between the strike of the foliation in the latter and the direction of the ranges. The highest peaks, however—those of Pachmarhi (4,380 feet)—are of horizontal mesozoic sandstones. Farther east still the Sátpuras consist entirely of horizontal traps, terminating in the plateau of Amarkantak, east of Mandla. East of this plateau, there is, north of Beláspur, a broad expanse of undulating ground at a lower level; and farther to the eastward, again, the metamorphic plateau of Chutia Nágpúr rises, capped in places by masses of horizontal trap and laterite. These formations were once apparently continuous across the low ground near Belåspur with the same strata on an equal elevation at Amarkantak. Similar outliers occur on the Bundelkhand plateau, north of the Narbada; all tending to the same conclusion—that the low valleys of Central India are merely denudation hollows, cut by rain and rivers out of the original plateau of the Peninsula. The chief exceptions to this law—the instances in which the strike and dip of the rocks appear to have produced important effects on the contour of the country—are to be found amongst the metamorphic and transition formations.

It is true that some small ridges are formed of azoic and mesozoic sandstones, in places where the beds of these systems have been disturbed; but the only important lines of disturbance in either appear to be due to older axes of metamorphic foliation; and it is a rare case to find that the strike of the sandstones appears to have much effect upon the directions of the hills and valleys. A possible exception occurs in the Damúda valley in Bengal; but even this is a disputed case; and the subject will be discussed in the chapters relating to the Gondwána system.

This remarkable absence in the Indian Peninsula of any evidence of disturbance in late geological times—a feature which abruptly distinguishes the whole area from the remainder of Asia—will be further noticed in the sequel: at present it is sufficient to remember that the principal mountain chains of the Indian Peninsula are, with one exception, not coincident with axes of disturbance or elevation, and to note the contrast in the Extra-Peninsular area.

The Arvali differs from the other great ranges of India in being entirely composed of disturbed rocks, with the axes of disturbance corresponding with the direction of the chain. The formations found in the

Arvali range belong to the transition rocks, and are of great antiquity; for the most part they are much altered; they are quite unfossiliferous, and there is evidence which renders it probable that the elevation of the range dates from a period anterior to the deposition of the Vindhyan rocks—themselves of unknown age, but almost certainly not of later date than older palæozoic; whilst the fact that these Vindhyan rocks are found almost horizontal in the neighbourhood of the Arvali range, on both sides of the chain, shews that here, as elsewhere in the Peninsula, the forces which have affected the non-peninsular area in later geological epochs have not been felt.

Mountain ranges of Extra-Peninsular area.—Passing to the other side of the Indo-Gangetic plain—no matter whether the region reached be to the eastward in Sind and the Punjab, to the northward in the Himalayas, or to the eastward in Chittagong and Burma—the mountain ranges, with the exception of a portion of the Assam range, are everywhere composed of disturbed and contorted beds, and the disturbance has invariably affected rocks of late geological age. The amount of alteration may be small or great; the hills may consist of simple anticlinal folds, as in Sind, or of the most complicated inversions, as in parts of the Himalayas; the strike of the bedding may vary from east and west to north and south; but two characters are constant—great disturbance affecting all the formations, and the coincidence of the direction of the ranges with synclinal and anticlinal axes.

Sind and Western Punjab.—In physical characters, as in geology, there is, to some extent, a passage between the two great and contrasting regions in the Western Indian provinces of Guzerat, Kattywar (Kathiawad), and Cutch (Kachh or Kach). These districts are, however, of no great extent, and may be neglected for the present. The rocks of the Eastern Salt Range in the Punjab differ from those of the western extremity, and the former approximate to the Peninsular type. Passing on to the Extra-Peninsular area, and commencing on the west in Sind, there are to the westward of the Indus several ranges having a general north and south direction. Of these, the most important is the Khirthar, forming the western boundary of Upper Sind. But little is really known of the geography west of the frontier. The Hala range of most maps is an imaginary chain of mountains; but there are several ranges immediately to the west of the frontier, parallel to the Khirthar. Farther to the westward, however, the ranges in Baluchistan run east and west parallel with the coast; and to the north of Sind, in the Mari and Bhúgti hills, the same east and west strike is found. These hills are still outside of British territory. The next range to the northward, the Sulemán, form-

ing the boundary of the Punjab, and extending from the frontier of Sind at Kashmor to the neighbourhood of Bannu, is again a north and south range, like the Khirthar. The Northern Punjab is traversed by a series of ranges having a general east and west strike, but being frequently curved, the curvature being greatest in the Salt Range, the most southern of all, and its continuation west of the Indus; whilst the ranges near Pesháwar and Attock are more nearly east and west. But little is known of the mountains in Afghanistan, nor have they much connexion with those of the Indian frontier: a north-east and south-west strike appears to prevail amongst them; but the Safed Koh, forming the southern watershed of the Kabul river, is said to strike east and west, like the Afridi hills and other ranges, of which it is a continuation.

Himalaya.—Throughout the western frontier of India there is a deficiency of rivers, owing to the small rainfall of the country; and no streams of any importance join the Indus from the west. The largest tributary is the Kabul river, which flows past Pesháwar, and runs into the Indus near Attock. The five great tributaries of the Indus—the Jhelum, Chináb, Rávi, Biás, and Sutlej—flow from the Himalayas; and, after traversing the Punjab, unite to form the Punjnad, before falling into the Indus from the eastward. The Himalayas may be considered as extending from the Indus to the Brahmaputra; these two rivers between them almost encircling the mountain zone of Northern India. Both streams rise in Tibet, and within a short distance of each other, and flow, the Indus to the north-west, the Brahmaputra, here known as Sangpo (Sanpoo), first east by south, then almost due east, until each, after a long course, breaks through the Himalayan chain, and reaches the plains of India—the Brahmaputra in Upper Assam, the Indus in the Northern Punjab.

Of the great mountain zone thus defined, the western portion alone is well known; and even here the geology requires much additional study. From a little east of the 80th parallel of east longitude even the geographical details of the Himalaya are but imperfectly represented on maps. The only accessible tract, Sikkim, does not extend far beyond the first great chain, and stops short of the main watershed.

The Himalaya, considered as a whole, forms a curved belt of mountains, with their convexity to the southward, running nearly from north-west to south-east to the westward, and from west to east to the eastward, the eastern extremity striking north of east. But, besides composing a great mountain chain, or series of chains, the Himalayas form the southern scarp of the Tibetan plateau—a tract of highland from about 12,000 to 16,000 feet above the sea. The northern scarp of this plateau is formed

by the Kuenlun, overlooking the lower plains of Eastern Turkestan and the Gobi desert.

The western terminal portion of the Himalayan chain—the only part, as already stated, that has been accurately mapped—comprises a number of great ranges, the majority of which have no settled appellations, but are commonly known by the terms applied to passes through them, or by the names of the districts traversed. The principal of these ranges are the Mustágh, Ladák, Zánskár or Báralácha, and Pir Panjál. The Mustágh, frequently called the Kárákoram, from a well-known pass, which, however, does not cross the range itself, forms the northern watershed of the Indus and its tributary the Shayok, and separates their drainage area from the upper waters of the Yárkand river. To the north-west the Mustágh range appears to curve round into the northeast-southwest chain of the Hindu Kush, and is of great height; its culminating peak, the nameless summit known on the Great Trigonometrical Survey maps as K2, rising to an elevation of 28,278 feet, and being only second to Mount Everest. The Ladák range intervenes between the Indus and Shayok. The Zánskár (Záskár) or Báralácha (Baralatsé) range divides the Upper Indus from the Jhelum and Chináb; the north-western continuation forming the northern boundary of the Kashmir valley, and terminating in the peak of Nanda Parbat. The Pir Panjál divides the Kashmir valley, drained by the Upper Jhelum, from the plains of the Punjab. All these ranges, it should be recollected, have a north-west to south-east direction; and to the westward there is a singularly abrupt change in the strike, as in the instance already mentioned, of the angle formed by the Mustágh range and the Hindu Kush. The angle made by the meeting of the Pir Panjál range, east of the Jhelum, and of the Murree and Hazára hills, west of that river, is even sharper; the latter ranges running at first north and south, forming an acute angle with the Pir Panjál, and then curving round south-west, and finally to west.

It is doubtful whether any of the ranges already noted in the terminal area should be considered the prolongation of the main Himalayan axis, although, if any be really a continuation of the Himalayas proper, it is either the Pir Panjál or the Zánskár range. The main range of the Himalayas appears more probably, so far as geological structure affords a clue, to commence on the westward in the Dhauladhár, a minor ridge rising from the banks of the Rávi close to Dalhousie, and extending to the east-south-east, till it rises into the main snowy range of the North-West Himalayas. Many geographers distinguish two parallel ranges from the neighbourhood of Simla to the eastward: the snowy range

proper, formed of the highest peaks; and a more northern ridge, forming the watershed between the Tibetan plain and the rivers running to the plains of India. Others consider the latter to be the true Himalayan range, and look on the higher peaks as belonging to the spurs between the rivers flowing from that range. It is certain that the great peaks, such as Nanda Devi (25,700 feet), Dhaulagiri (26,826 feet), Mount Everest (29,002 feet), Kinchinjinga (28,156 feet), Chumalari (23,929 feet), &c., are separated from each other by deep valleys through which flow streams coming from the northern range, and that, although the peaks of the latter are inferior in elevation, the passes by which it is traversed are much higher; but it has not yet been ascertained whether the great peaks are on the strike of any continuous band of rock, or whether they merely consist of hard nuclei left undenuded.

Along the southern base of the Himalayas, and parallel with the general direction of the mountains, a series of comparatively low ridges extends, formed of tertiary rocks, and separated from each other or from the rocks of the main range by valleys called dúns. These fringing ranges of the later formations are known generally as the Sub-Himalayas; the most important being the Siwalik hills, a term especially applied to the hills south of the Deyra Dún, but frequently employed in a wider sense than its original application. To the eastward, the Sub-Himalayan ranges are less conspicuous than to the westward; but they are only locally wanting altogether, and are to be traced almost throughout the Himalayan border, from the Punjab to Upper Assam. The rivers running from the Himalayas to the Ganges and Bráhmaputra, although in many cases of considerable size, are in general formed by the union of a number of comparatively unimportant hill streams; the largest and best known of these rivers, beginning from the west, are the Gogra (Ghogra), Gandak, Kosi (Koosee), and Tista (Teesta).

Ranges and rivers of Burma, &c.—The hills immediately south of the Bráhmaputra belong to two distinct systems. The chain, known collectively as the Assam range, and locally as the Gáro, Khási (Khasia or Cossya), Jaintiá (Jyntia), and Nága hills, runs east and west to the westward and turns to north-east to the eastward, being nearly parallel to the Himalayas throughout. The western part of this range, like the hills of Kattywar and Cutch to the west of the Peninsula, presents a remarkable combination of peninsular and extra-peninsular rocks. It will be shewn that in this direction also some of the peninsular formations are found at the base of the Himalayas; but the peculiarity of the Gáro and Khási hills is, that there is less marked coincidence between the strike of the newer rocks and the direction of the range than in the

extra-peninsular area generally. To the eastward, in the Nága hills, the usual connexion between the strike of the rocks and the direction of the ranges reappears; and a monoclinal axis may be traced along the southern face of the Jaintiá, Khási, and Gáro hills themselves; but the greater portion of the latter form a plateau, on which the mesozoic and tertiary formations are horizontal, or nearly horizontal. The most important ridge of the Nága hills is the westernmost portion, known as the Barail-Pátkai range; and this chain is distinctly cut off from the western plateau of the Assam range by an abrupt change of dip in the rocks, and geographically by deep valleys.

The Súrma (Soorma) or Bárak river drains the southern slopes of the Assam range, and divides it from the great hill region of Burma. In North-Eastern Manipur (Muneepoor) there is a transition from the north-east—south-west strike of the Nága hills to the north and south (or north-by-west to south-by-east) direction of the Burmese mountain chains. The north and south direction is nearly constant throughout British Burma, and continues, curving to the south-east, in the Malay Peninsula. The great Burmese rivers, the Irawadi and Salwin, and the less important streams, the Sittoung, Tenasserim, &c., ran from north to south; and the principal hill ranges are the Arakan Yoma, between the Irawadi and the sea; the Pegu Yoma, between the Irawadi and Sittoung; and a number of less defined chains, formed of older rocks, east and west of the Salwin and throughout the Tenasserim provinces. None of these ranges within British territory attain a height exceeding 7,000 feet.

Geological formations in general.—After the above brief sketch of the more conspicuous geographical features of India and the surrounding countries—a sketch in which one of the most important distinctions between the peninsular and extra-peninsular areas has been pointed out—it will be well to proceed at once to a comparison of the geological formations found in the different regions. The contrast here will be found quite as great as in the case of the physical geography. Throughout the peninsular area, there is, from the lowest to the highest formation, a most remarkable deficiency of fossiliferous marine rocks; the few that occur being almost exclusively found in the neighbourhood of the present coast, or else in the desert between the Arvali chain and the river Indus. With one solitary exception—that of some cretaceous beds occupying a limited area in the Narbada valley—no instance is known of marine fossils being found in the Indian Peninsula, to the south-east of the Arvali range, at a greater distance than 70 miles from the coast.

The absence of marine fossils is certainly not due to the alteration the strata have undergone, nor to the deficiency of rocks suited for the

preservation of organic remains. Land and freshwater organisms are found in considerable quantities in some of the mesozoic and cænozoic formations; and it is possible that the lowest fossiliferous Gondwána beds may be of upper palæozoic age. Even at a lower horizon, in the ancient Vindhyan formation, limestones and shales, to all appearance perfectly adapted for the preservation of fossils, occur in profusion; and it is surprising that no trace of organic remains has ever been detected in the transition series, many of the slates, shales, and limestones being no more altered than some of the older fossiliferous beds of Europe, and even of the Himalayas. When it is recollected how long the "grauwacke" of Western Europe was supposed to be unfossiliferous, some faint hope may still survive that fossils may yet be found in the Vindhyan and transition rocks of India; but the European Silurian and Cambrian beds yielded organic remains in abundance to the first attempt at systematic exploration; whilst the Vindhyans, Bijáwars, Kadapahs, Karnuls, and other ancient Indian formations have been searched repeatedly, but without success, by experienced geologists, who had throughout their lives been engaged in similar researches. It cannot be said that the search is hopeless, in the Upper Vindhyans especially; but it may fairly be doubted whether any conspicuous marine organisms, such as mollusca, corals, or crustacea, will be detected.

Of the few marine beds hitherto found in the Indian Peninsula, none are older than jurassic. Even the jurassic marine beds are well represented only in Cutch and the neighbouring countries, the known representatives of the series on the eastern coast of the Peninsula being but poorly developed. The cretaceous marine rocks are better represented; although a considerable portion of the series is wanting, and the area occupied is very small. The marine beds of the tertiary period are also, so far as is known, very ill-developed, or wanting, except in Guzerat and Cutch.

In the extra-peninsular area, on the other hand, marine fossiliferous rocks of silurian, carboniferous, triassic, jurassic, cretaceous, eocene, and miocene age have been found; and in many cases a complete sequence of the different sub-divisions of each epoch has been detected; although far less time and labour have been devoted to the examination of the country than have been given to the Peninsula, and although the geology of the area is in general much more complicated, and the task of surveying surrounded by greater difficulties.

List of peninsular formations.—The following is a classified list of the formations in the Indian Peninsula, inclusive of Kattywar and Cutch. The great European sub-divisions of the geological sequence—palæozoic, mesozoic, and tertiary or cænozoic—are ill adapted for the classification of

the Indian beds; and in several instances, as will be shewn more fully in other chapters of this work, the correlation of the strata found in the Peninsula of India with the geological series elsewhere is far from satisfactorily decided. The lower formations in this list are simply classed as azoic. The sub-divisions are not always strictly consecutive; some of the marine cretaceous rocks being of the same age as the Deccan traps, and the marine jurassic beds being contemporaneous with the Upper Gondwánas.

CLASSIFIED LIST OF FORMATIONS IN PENINSULAR INDIA.

				Approximate maximum thickness.
	RECENT AND POST-TERTIARY.		Blown sand. Soils, including black soil or regur. Modern alluvial deposits of rivers, estuaries, and the sea coast. *Khádar* of Indo-Gangetic plain, &c. Raised shell beds of coast. Low-level laterite. Older alluvial deposits of Ganges, Narbada, Godávari, &c. Cave deposits.	Unknown; 700 feet deepest boring.
CENOZOIC.	TERTIARY .		Miliolite of Kattywar. Pliocene, miocene, and eocene (nummulitic) beds of Cutch and Guzerat. Sandstones, clays, and lignites of the west coast, Travancore and Ratnagiri. Cuddalore sandstones. High-level laterite.	2,700
CENOZOIC. / MESOZOIC.	DECCAN TRAP SERIES.		Upper traps and intertrappeans of Bombay. Middle traps. Lower traps and intertrappeans of Central India, Rájámahendri, &c. Lameta or infratrappean group. Infratrappeans of Rájámahendri.	6,000
MESOZOIC.	MARINE CRETACEOUS ROCKS.		Arialúr, Trichinopoly, and Utatúr groups. Bágh beds. Neocomian of Cutch.	3,000
MESOZOIC.	MARINE JURASSIC ROCKS.		Umia, Katrol, Chári, and Pachham groups of Cutch. Jesalmir limestones. Tripetty and Ragavapuram beds of east coast.	6,000
MESOZOIC.	GONDWÁNA SYSTEM.	*Upper*	Cutch and Jabalpur. Rájmahál and Mahádeva.	11,000
PALC.?	GONDWÁNA SYSTEM.	*Lower*	Panchet. Damúda:—Ránigauj or Kámthi, ironstone shales, and Barákar. Karharbári and Tálchir.	13,000
AZOIC.	VINDHYAN SERIES.	*Upper*	Bhánrer (Bundair). Rewah. Kaimur (Kymore).	12,000
AZOIC.	VINDHYAN SERIES.	*Lower*	Karnul. Bhima. Son. Semri.	2,000 ?
AZOIC.	TRANSITION OR SUB-METAMORPHIC ROCKS.	*Upper*	Gwalior, Kadapah, and Kaladgi series . .	20,000
AZOIC.	TRANSITION OR SUB-METAMORPHIC ROCKS.	*Lower*	Bijáwars. Chámpanir beds. Arvali. Maláni beds. Transition rocks of Behar and Shillong (the last extra-peninsular).	
AZOIC.	METAMORPHIC OR GNEISSIC		Gneiss, granitoid and schistose rocks, &c. . . .	?

The following is the succession of the more important fossiliferous peninsular rocks, the marine beds being omitted from the sequence, but classed as equivalent to their supposed representatives amongst the formations without marine fossils :—

		Peninsular rocks.	*Supposed marine equivalents.* Indian.	*Supposed marine equivalents.* European.
CÆNOZOIC		High-level laterite . .	Nummulitic	Middle eocene.
	DECCAN TRAPS.	Upper Deccan traps .	?	Lower eocene.
MESOZOIC	DECCAN TRAPS.	Middle traps	Arialúr	Upper chalk.
		Lower traps	Trichinopoly	Lower chalk.
		Infratrappeans or Lameta	Bágh beds, Utatúr.	Upper greensand.
	GONDWÁNA.	Jabalpur and Cutch. Mahádeva and Rájmahál	Umia and Katrol. Chári and Pachham.	Jurassic.
		Panchet		Triassic.
PALÆOZOIC		Damúda . . . . Tálchir		Upper palæozoic ?

It will be seen at once that the geological horizon of the upper mesozoic and tertiary beds is ascertained with a fair amount of precision; but that the determination of the position in the series to be assigned to the Lower Gondwána formations is far more doubtful, and that nothing is known of the age of the Vindhyans and older rocks.

List of Extra-Peninsular formations.—Owing partly to imperfect knowledge of the ground, but still more to the extent to which the different tracts of Extra-Peninsular India comprised in British territory are isolated and separated from each other by such regions as Nepál and Afghanistan, entirely inaccessible to Europeans, the correlation of the various formations in the extra-peninsular region with each other is more imperfect than in the peninsular area. This circumstance, however, in no way affects the contrast between the rocks in the two areas. The interstratification in Kattywar and Cutch of certain peninsular formations with marine beds belonging to the extra-peninsular types has already been noticed; but the geology of Kattywar is as yet but imperfectly known, and the only peninsular formations found in Cutch are of newer mesozoic or tertiary age. A thin representative of the Deccan trap is also found in Sind. At the eastern end of the Salt Range in the Punjab are found several groups of unfossiliferous sandstones, having some resemblance in general character to the Gondwána and Vindhyan systems of the Peninsula; and as the age of some of the Eastern Salt Range groups is approximately determined by the interstratification amongst

them of beds representing the fossiliferous marine rocks of the western portion of the range, some clue may perhaps here be afforded to the age of the peninsular rocks. Hitherto, however, no such clue has been obtained; the Salt Range is at a considerable distance from all the Gondwána and Vindhyan rocks of the Peninsula, and none of the unfossiliferous Salt Range groups has as yet been identified with any of the peninsular formations.

With the exception of Sind, there are but two localities in Extra-Peninsular India where peninsular rocks are found. One of these is at the base of the Himalayas, in Sikkim and Bhután, where fossiliferous Damúda (Lower Gondwána) beds occur. The other is in the Assam hills (Khási and Gáro), where representatives of the metamorphic and cretaceous (marine) rocks of the Peninsula, and in all probability of the transition beds and of the Rájmahál traps, are found. But, in the first instance, the relations between such Himalayan rocks as are associated with the Damúdas and those of other parts of the Himalayas are extremely doubtful; and it is not even conclusively settled whether the Himalayan rocks in question are higher or lower in position than the Damúda beds themselves; and in the Assam hills none of the older Himalayan formations have been detected: they appear to be replaced by peninsular types.

Of the extra-peninsular rocks two lists are given below: in the first, the representatives of different geological horizons in the various tracts are enumerated; and in the second, an attempt has been made to exhibit the probable correlation of the rocks in the different parts of the area, so far as the information available extends. In both lists, an asterisk serves to shew that a formation is unfossiliferous, and a note of interrogation that the position is doubtful.

CLASSIFIED LIST OF FORMATIONS IN EXTRA-PENINSULAR TERRITORIES BELONGING TO INDIA.

RECENT AND POST-TERTIARY. Alluvial and lake deposits. Sub-Himalayan high-level gravels.*

PLIOCENE. Upper Manchhars of Sind. Upper and middle Siwaliks of Sub-Himalayas, Punjab, &c. Mammaliferous deposits of Western Tibet. Dehing group* of Assam. Fossil-wood deposits of Pegu.

MIOCENE. Lower Manchhars and Gáj of Sind. Murree beds* (in part). Náhan.* Tipam group of Assam ?* Pegu group of Burma.

EOCENE	*Upper*	Nari group of Sind. Kasauli and Dagshai* groups of Sub-Himalayas.
	Middle	Nummulitic limestone of Sind, Punjab, Assam, Burma, &c. Khirthar of Sind. Subáthu of Sub-Himalayas. Indus or Shingo beds of Western Tibet. Coal-measures of Assam?
	Lower	Ranikot beds of Sind. Lower nummulitics of Salt Range.
CRETACEOUS	*Upper*	Deccan trap.* *Cardita beaumonti* beds and cretaceous sandstones of Sind. Olive group of Punjab Salt Range. Disang group* of Assam? Upper cretaceous of Khási Hills. Negrais beds of Burma? (*N.B.*—It is not certain that some of these formations may not be, in part at least, eocene.)
	Middle	Hippuritic limestone of Sind. Cretaceous beds of Mount Sirban in Hazára and of Kohát. Chikkim beds of North-Western Himalayas. Cretaceous beds of Assam, in part. Mai-i group of Burma.
	Lower or *Neocomian.*	Beds in Chicháli Pass, Salt Range.
JURASSIC	*Upper*	Salt Range. Gieumal and Spiti beds of Northern Punjab and North-Western Himalayas.
	Middle	Variegated group of Salt Range. Part of Spiti shales in North-Western Himalayas?
	Lower or *Lias.*	Upper Tagling limestone of North-Western Himalayas. Sylhet trap?*
TRIAS	*Upper including Rhætic.*	Lower Tagling limestone of North-Western Himalayas. *Nerinæa* beds of Mount Sirban, Hazára. Pára limestone of North-Western Himalayas. Beds with *Megalodon* and *Dicerocardium* at Mount Sirban, Hazára.
	Middle	Salt Range? Liláng series of North-Western Himalayas and Kashmir. Axial group of Burma?
	Lower	Ceratite beds of Salt Range. Infra-triassic* of Hazára, in part?
PERMIAN & CARBONIFEROUS.		Salt Range carboniferous limestone. Damúdas of Sikkim and Bhután? Infra-triassic* of Hazara? Kiol limestone* of Pir Panjál? Król* limestone and Infra-Król* of Western Himalayas? Kuling series of North-Western Himalayas and Kashmir. Maulmain group of Burma.
SILURIAN		*Obolus* beds of Salt Range. Attock slates* of Upper Punjab? Slates* and traps* of Pir Panjál and Kashmir? Muth and Bhábeh series of North-Western Himalayas. Blaini* and Infra-Blaini* of Simla area?
INFRA-SILURIAN.		Salt marl* of Salt Range? Gneiss* of Pir Panjál and Ladák. Upper gneiss* of Zánskár range. Shillong series* of Assam hills? Mergui group?*
		Lower or central gneiss* of Himalayas. Gneiss* of Assam and Burma.

The thickness of the different formations has only been determined in a few instances; so few that it is useless to quote them. The amounts are very great, the tertiary rocks alone attaining a vertical development in places, as in Sind, of nearly 30,000 feet.

DISTRIBUTION OF EXTRA-PENINSULAR FORMATIONS.

	Sind.	Punjab Salt Range.	Northern Punjab.	N. W. Himalaya and Tibet.	Lower Himalaya and Sub-Himalaya.	Assam.	Burma.
Pliocene	Manchhar	Siwalik	Siwalik	Mammaliferous beds...	Siwalik	Dehing group*	Fossil-wood group.
Miocene	Gáj	......	Murree beds*	......	Nahán*	? Tipam group*	Pegu group.
Eocene	Nari	......		......	Kasauli & Dagshai*	Nummulitic and coal-measures.	Nummulitic.
	Khirthar	Nummulitic	Nummulitic	Indus or Shingo beds	Subáthu		
	Ranikot	Lower Nummulitic	?	......	......	......	......
Cretaceous	Deccan trap* Olive shales & sandstones.	Olive group	?	......	......	? Disang group*	? Negrais group.*
	Hippuritic limestone.	......	Cretaceous of Mount Sirban and Kohát.	Chikkim beds	......	Cretaceous	Mai-i-group.
	......	Neocomian	......	......	......	......	......
Jurassic, *including* Lias.	......	Upper Jurassic	Upper Jurassic	Gieumal sandstones	......	......	......
	......	Middle Jurassic (Kelloway).	?	Spiti shales.	......	......	......
	......	......	......	Upper Tagling limestone.	......	Sylhet trap*	......
Triassic, *including* Rhætic.	......	......	*Nerinæa* beds	Tagling limestone	......	......	......
	......	......	Upper trias of Mount Sirban.	Pára limestone	......	......	......
	......	Middle trias	......	Liláng series	......	......	Axial group.
	......	Lower trias	? Infratriassic & Tanol*	?	? Damúdas	......	......
Carboniferous	......	Carboniferous limestone.	......	Kuling series and ? Kiol limestone.*	? Król* and Infra-Król.*	......	Maulmain series.
Silurian	......	......		Muth series	? Blaini*	......	......
	......	*Obolus* beds	? Attock slates*	Bhábeh series	? Infra-Blaini*	......	......
Infra-Silurian	......	? Salt marl*	Metamorphic*	? Upper gneiss*	......	? Shillong series*	? Mergui series.*
	......	......	......	Lower or Central gneiss.*	Gneiss*	Gneiss*	Gneiss.*

Summary of geology.—With these data before us, we may proceed to a brief summary of the geological history of India. This summary will serve to shew that, despite the imperfection of the geological series developed in the Peninsula, there is evidence of a singular permanency of conditions and freedom from severe disturbance at all periods after early palæozoic times. Up to the tertiary epoch the same absence of contortion appears to have prevailed in the extra-peninsular area also, but in later geological times extensive disturbance has affected many parts of the latter country. In this summary, it will be necessary frequently to anticipate arguments used in the succeeding chapters, in which, however, fuller details will be given.

Although, as has already been said, no marine fossils of older date than jurassic have been found in the Indian Peninsula, it by no means follows that the ancient azoic rocks are not of marine origin. All that can be said of the peninsular gneissic and transition series is, that they are ancient sedimentary beds: whether deposited in the sea or in rivers or lakes, it is impossible to tell. The rocks of these formations may have been originally fossiliferous; for the amount of alteration they have undergone would have sufficed in many cases to obliterate all traces of organic remains; but the absence of fossils in the much newer Vindhyans is not so easily explained; and even some of the transition beds are not more altered than rocks in which fossils have elsewhere been detected.

Metamorphic rocks.—The gneissic rocks of the Indian Peninsula are developed in three areas—the peninsular area proper, comprising the greater portion of Bengal and Madras, the Bundelkhand, and the Arvali—and appear to include representatives of two formations at least, differing in age. The older, which will be described as the Bundelkhand gneiss, is shewn to be more ancient than the gneissic formation throughout the greater part of India, by the circumstance that certain transition rocks rest without alteration and unconformably on a denuded surface of the former, but are altered and intersected by granitic intrusions in the neighbourhood of the latter; so that there is to all appearance a passage between the transition beds in question and the peninsular gneiss. It is manifest that the Bundelkhand gneiss was altered before the deposition of the Bijáwar transition rocks, and it appears probable that the peninsular gneiss was metamorphosed after Bijáwar times; and it is a reasonable inference that the peninsular gneiss, whether composed of altered Bijáwar rocks or not, is the later of the two gneissic series in origin as well as in period of metamorphism. The relative age of the gneiss occupying the Arvali area in Rájputána is uncertain.

There are no data known by which the relations of the oldest Himalayan rocks to the metamorphic formations of the Peninsula can be determined. There is a well-marked mineralogical distinction between the older gneiss of the Himalayas and both of the peninsular types—that of Bundelkhand and that of the Peninsula proper. The most important differences are, that the Himalayan gneiss is usually white or grey, the common felspars being orthoclase and albite, whilst the ordinary peninsular gneiss is pink, the prevailing felspars being orthoclase and oligoclase; and that the former rock is more micaceous, whilst the latter contains more hornblende. The Himalayan gneiss, too, is, as a rule, more uniform in character; it contains far more mica schist, but less quartzite, and very little hornblendic or syenitic gneiss; whilst in the peninsular forms of the rock the different beds vary greatly in mineral characters, and a highly hornblendic variety is much more prevalent than mica schist.

The metamorphic rocks of the Assam hill range belong, as has already been mentioned, to the same mineralogical type as the Bengal gneiss; and hills of this rock are found in places rising out of the alluvium of the Assam valley, close to the base of the Himalayas. The gneissic rock of Assam and that of the Himalayas are nowhere seen in contact; but the distinction in mineralogical character is absolute. In the absence of any contact-section there is, however, no clue to the relative age of the two series: it is impossible to say whether the Himalayan gneiss is older than that of the Peninsula, or *vice versâ*. It should also be recollected that the gneiss of the Western Himalayas is divided from that of the mountains north of Assam by nearly 500 miles of unexplored country in Nepál.

The contrast between the peninsular aud extra-peninsular regions begins thus with the oldest known rocks; but it is evident that the limits of the areas were then different from what they subsequently became. Not only are the metamorphic formations of the Assam hills similar to those of the Peninsula, but the gneiss of Burma resembles the peninsular type rather than the Himalayan.

Although the metamorphic rocks are frequently granitoid, true granite only occurs amongst them in the form of veins; no large areas are known. Granitic intrusions are of larger dimensions in the older submetamorphic or transition rocks than in the gneissic series.

Transition rocks.—The transition or submetamorphic rocks of India consist of schists, slates, quartzites, breccias, limestones, &c.; they occupy a considerable area, and attain a very great thickness, but their history is as obscure as is that of the gneiss. They have been classed in two

sub-divisions: the first, which is supposed to be the older, exhibiting by partial metamorphism, conformable sequence or granitic intrusion, a close connexion with the gneissic strata; the second, shewing no such relation. The transition rocks are also divided into several groups, distinguished as much by locality as by mineral characters. All these details will be found in the second and third chapters of the present work: the only points of importance to be now noticed are the relations between the transition series, as a whole, and the older and newer rocks of the Peninsula.

The most important of these relations may be summed up in the fact that some of the transition beds appear to have been deposited previously to the last great disturbances that affected the strata of the Peninsula; whilst later beds, when tilted or contorted, are only affected within limited areas. Faults of considerable magnitude have certainly been formed at a subsequent period; but still the great lines on which the rocks of the Peninsula have been moulded were more than traced before the transition epoch had passed away: they were so firmly laid down, that they have determined the main features of the land, wherever these are dependent on the strike of the rocks; and it is remarkable how often the minor disturbances of a later date conform to the direction of the foliation in the metamorphic rocks. For although, with the exception of the Arvali, the great ranges of the Indian Peninsula appear almost solely due to the action of denudation, and although the direction of these ranges is independent of the strike of the newer rocks of which the hills themselves are composed, many of the minor ranges and of the smaller river valleys coincide in direction with the foliation of the gneiss, or the stratification of the older transition rocks. It matters little whether the gneiss foliation be due to bedding or cleavage: if the former, the high angles are evidence of great lateral pressure; if the latter, the very existence of cleavage proves the same; and the parallelism of the foliation throughout large areas, and sometimes over hundreds of miles, as in the Narbada valley, shews how extensive were the disturbing causes to which this uniformity of result is due. It is far from improbable that great mountain ranges were formed in the Indian Peninsula before the dawn of geological history, as recorded by organic remains, and that the small ridges of metamorphic and transition rocks now remaining are but the remnants that have escaped denudation.

It is difficult to say how far the eruption of igneous rocks is connected with areas of disturbance: the problem has not yet been solved. Independently, however, of the granitic intrusions already noticed, igneous rocks, often to all appearance of contemporaneous origin, are almost everywhere associated with the transition strata. Diorite or an allied

rock, often greatly altered, is found in the Shillong transition series, the beds of Chutia Nágpúr (Chota Nagpore), the Bijáwars of Bundelkhand and the Narbada valley, the Gwalior, Arvali, and Chámpanir beds, and the Kadapah (Cuddapah) series; whilst the Maláni transition beds are chiefly composed of felsites. Many of the "trappoid" rocks associated with the various transition strata, to judge by the descriptions given, have the characters of altered subaqueous volcanic tuffs; and this may indicate that the associated transition beds are of marine or lacustrine origin. In fluviatile, as in other subaërial deposits, the character of the associated volcanic rocks would probably be different. Some of the transition igneous rocks, however, have not the characters of subaqueous tuffs.

Vindhyan series.—The break between the uppermost transition beds and the quartzite sandstones, shales, and limestones of the Lower Vindhyans does not appear to be very great; for although the two series are nearly always unconformable, where the newer is seen to rest upon the older, there are several obscure sections indicating passage; and in the Godávari valley it has hitherto proved impracticable to distinguish the limits of the two series with certainty. The Vindhyans, however, and especially the Upper Vindhyans, have a far more recent aspect than the transition rocks: a distinction due doubtless to the much smaller amount of disturbance, and consequent alteration experienced by the newer series. It is an exception to find the Vindhyans, upper or lower, dipping at high angles; and over large areas these rocks are nearly horizontal.

The thickness of 2,000 feet assigned as a maximum to the Lower Vindhyans is probably too little; but still they are far inferior in development to the underlying transition beds and to the overlying Upper Vindhyans. It is the more surprising on this account to find that the Lower Vindhyans have so great a horizontal extension, and that they are found, with but small change in mineral character, from the Son valley to Kadapah in one direction, and to the neighbourhood of Bijápúr in another, a distance in each case of 700 miles. In the Son area, too, some peculiar beds of trap-like rock occur, similar to those already noticed as being intercalated in the transition series of Gwalior, Kadapah, and other places, and as having the characters of subaqueous volcanic tuffs. These facts are in favour of the marine origin of the Lower Vindhyans. But, on the other hand, the area occupied by this series is not continuous; and in one locality at all events, south of the Son valley, there are indications of an ancient barrier between different basins of deposition, whilst the singular absence of organic remains is rather in favour of freshwater origin; freshwater beds being, as a rule, less fossiliferous than

marine. At the same time, there is always a possibility that these formations may have been deposited at an epoch anterior to the existence of life; although, in face of the great probability that the earliest forms of organised beings existed long anterior to the appearance of *Brachiopoda* and *Crustacea* in the Cambrian formation, and even of *Foraminifera* in the Laurentian, the likelihood of the Vindhyans dating from a time when the world was devoid of life appears small. It is possible that the tropics were too hot for life, even after the polar regions and temperate zones were inhabited; but this is open to question on physical grounds, and appears contradicted by the similarity of silurian fossils in the southern hemisphere to those in the northern. Had life originated independently in both hemispheres, a wide divergence of forms might have been anticipated in the earlier formations between the two areas on opposite sides of the equator. At the same time, it is quite possible, and even probable, that marine life existed long before the fresh waters and the land were inhabited; and the land and fresh waters of the tropics may have been too hot for animals or plants after the sea teemed with living beings. Unfortunately, the first element of the question,—the enquiry whether the direction of the earth's axis has been constant, and consequently whether the present tropics have always been in the neighbourhood of the earth's equator,—has not been decided by mathematicians; and it will be shewn presently that there are some very curious indications of a low temperature having prevailed in the Indian area at very ancient epochs.

The Upper Vindhyans, consisting chiefly of fine, hard, red sandstone, with subordinate bands of shale and limestone, are quite parallel, and apparently conformable, to the lower, as a rule; but still there is extensive overlap of the lower by the higher series, and some amount of local unconformity, shewn by the presence of detritus, derived from the older beds, in the conglomerates of the newer. The area of the Upper Vindhyans is almost restricted to the great tract extending from Behar to the Arvali hills; and differs so greatly from that of the Lower Vindhyans, that a great change probably took place in the area of deposition in the interval between the formation of the two; whilst there is much in the peculiar conditions of the rocks, and in the features of the boundary, to indicate that the Upper Vindhyans may have been deposited in a land-locked area. The persistent red colour of the Vindhyan sandstones may perhaps also indicate deposition in an inland basin; for although Professor Ramsay's views on the subject[1] are not universally conceded, there can be no doubt that the old and new red sandstones of England, and

[1] Q. J. G. S., 1871, pp. 197, 241.

many similar rocks elsewhere, were in great part formed in lakes or lagoons, and not in an open sea. The same observation applies, though less generally, to the Lower Vindhyans and many of the transition rocks; several of the beds, and especially the sandstones or quartzites, having the same red colour as the Upper Vindhyans.

It has already been intimated that the elevation of the Arvali range probably dates from pre-Vindhyan times; and the supposed Vindhyan rocks of Jodhpur to the west of the Arvali, if really of contemporaneous age with the main area of Upper Vindhyans, may have been deposited in a second basin.

It is not possible, in the absence of fossils, to express any decided opinion as to whether the Upper Vindhyans are of marine or freshwater origin. The prevalence of sandstones, the subordinate character of the limestones, the approximate limitation to a defined, although extensive, tract, the want of fossils, and, considering the probability that the series was deposited in an inland basin, the absence of any deposits of salt or gypsum,—are all in favour of freshwater origin; but it cannot be said that these arguments are conclusive. The frequent occurrence of rippling on the shales and finer sandstones indicates that the rocks are shallow-water deposits. No contemporaneous igneous rocks are known.

The Vindhyans are the latest azoic rocks of the Peninsula. So far, there is no indication of any defined geological horizon. The complete severance between the Vindhyans and the Gondwánas, the next series in ascending order, prevents the deduction of any inference from the latter as to the age of the former. The only clue to the magnitude of the break is furnished by the relations between the Gondwánas and the azoic slates of the Sikkim Himalayas. The details will be found in Chapter XXV. The evidence is too uncertain to be accepted with much confidence; but, so far as it goes, it is in favour of the Vindhyans being classed as very ancient, and perhaps as pre-silurian.

Probable conditions of deposit.—From such data as have been hitherto afforded but little can be inferred as to the history of the Peninsula in pre-Vindhyan periods. The peculiarities exhibited by the various local groups of transition rocks are in favour of deposition in isolated areas, and consequently of a considerable proportion of the country having been above the sea; and there is even a greater probability, that India was a land area, or part of a land area, in Upper Vindhyan times than in the previous eras. The great break which succeeds the Vindhyan age may mark an extensive and prolonged period of terrestrial conditions. For any indication of the history of the country in early palæozoic times, we must leave the Peninsula, and turn to the Punjab and

the Himalayas. The oldest beds to the eastward, in Burma, are too little explored to afford information, and, so far as they are known, they present no marked distinction from the peninsular rocks; whilst the metamorphic and transition formations of the Assam hills are similar to those of Bengal. Along the western frontier, in the Punjab and Sind, no old beds are known; and proceeding to the northward, the first palæozoic rocks exposed at the surface within Indian limits are in the Salt Range of the Punjab.

Palæozoic rocks of Salt Range.—In this Salt Range there is a very remarkable and interesting phenomenon. At the eastern termination of the range almost all the older rocks consist of unfossiliferous sandstones, whilst to the westward marine rocks containing fossils prevail. The very oldest formation, however, is destitute of fossils throughout the range; and the most ancient form of life occurs near the eastern end of the hills. The idea, suggested by Dr. Waagen, that the Salt Range marks a portion of the limit of the ancient peninsular land, is highly probable; but the evidence of the replacement of marine formations to the westward by unfossiliferous sandstones, indicating freshwater or terrestrial conditions to the eastward, begins with the carboniferous period.

The oldest group of the Salt Range is a bed, at least 1,500 feet thick in places, of bright-red marl, with thick beds of rock-salt and gypsum. This is succeeded in ascending order by from 250 to 450 feet of deep purple sandstone, and then comes the lowest band containing recognisable fossils—a belt of black shale with calcareous layers. In the two lower groups only obscure and indistinct traces of fucoids and markings resembling annelid burrows have been detected; but in the shale Mr. Wynne obtained a small brachiopod closely resembling *Obolus*. This probably indicates marine conditions and a lower palæozoic horizon. Above the shale comes another unfossiliferous bed, the "magnesian sandstone," a pale-coloured sandy dolomite, about 200 feet thick. At the east end of the range this is succeeded by bright-red clays and flaggy sandstones, and then come upper mesozoic or tertiary rocks. Various changes take place in the series farther west, and it is by no means certain how far the formations at the two ends of the range represent each other; but to the westward the various unfossiliferous sandstones die out, and the salt marl is immediately overlaid by carboniferous limestone, with the typical fossils, *Productus, Spirifera,* &c. It is clear that there must be a great break in sequence between the salt marl and the carboniferous limestone; for several hundred feet of sandstones intervene between the two, where the limestone first makes it appearance in the

middle of the range; and the salt marl is in all probability of silurian age at the latest.

The red marl, with thick beds of salt and gypsum at the base of the section, can scarcely have been formed otherwise than in an inland basin: whether in partial or occasional communication with the sea or not it is, of course, impossible to say. The interstratification of the *Obolus* band with the unfossiliferous sandstones very probably indicates alternation of marine and terrestrial conditions; and in upper palæozoic times the sea evidently occupied the region now forming the western portion of the range. But the fossils of the Salt Range carboniferous limestone are in many cases the same as those found in Europe, in America, and in Australia; and to the westward and northward, similar limestone, with the same shells, is found in the Sulemán range and in Kashmir, and far to the eastward, in the trans-Himalayan area; so that it is a reasonable inference, that the sea in which the carboniferous limestone of the Salt Range was deposited was part of the great ocean. At the same time if, as appears probable, some of the sandstones to the eastward are of contemporaneous origin with the upper palæozoic limestone of the Western Salt Range, the existence of a coast line is indicated, even if the sandstone beds be not of freshwater origin; for many conglomeratic bands occur.

Oldest rocks of Northern Punjab, Kashmir, &c.—Farther to the north in the Punjab, in the neighbourhood of Attock and of Abbottabad in Hazára, the oldest unaltered rocks are unfossiliferous slates, with some limestones, and occasional bands of basic volcanic rocks, perhaps contemporaneous. In Hazára, near the Indus, metamorphic rocks occur; but their relations to the slates are not determined with certainty, the one being possibly in part an altered form of the other. The carboniferous limestone has not been found in place in the extreme north of the Punjab; but some mesozoic beds overlying the Attock slates are related to Himalayan rocks of the same age; and farther to the eastward, in Northern Kashmir, and other parts of the North-West Himalayas, similar mesozoic rocks rest upon carboniferous limestone; and this last is succeeded in descending order by a great mass of slates, sandstones, quartzites, &c., resting, in turn, upon gneiss. In Kashmir itself and its neighbourhood no fossils have been found below the carboniferous formation; but farther to the south-eastward, in Spiti, two fossiliferous bands, the Bhábeh and Muth beds of Stoliczka, have been detected, both probably of silurian age. Still farther east, too, in the north of Kumaun, silurian fossils have been discovered in considerable quantities. There is reason for believing that the Attock slates are a continuation to the westward of the slates of Lahúl,

Kishtwár, and Kashmir; that the latter are representatives of the silurian rocks of Spiti and Kumaun, and that the whole of these rocks are marine. Contemporaneous traps are associated with these silurian formations both in Spiti and Kashmir, and may in great part be of subaqueous origin; though the amygdaloidal eruptive rocks of the Kashmir valley rather resemble subaërial lava flows in some respects. On the whole, the probabilities are in favour of marine conditions having prevailed throughout the extreme north of the Punjab, Kashmir, and the neighbouring countries north of the Dhauladhár and main Himalayan range in lower palæozoic times.

Oldest rocks of Himalaya.—The formations in the Western Himalayan area of earlier age than silurian are quite unfossiliferous and much altered. They consist of gneissic rocks of two ages: the central gneiss of Stoliczka, and a newer series resting upon the older, and passing upwards into the silurian slates, which are shewn to be unconformable to the older gneiss by containing large quantities of fragments derived from it. Neither of these forms of gneiss affords any distinct clue to the conditions under which it was originally deposited; but the newer probably consists of altered marine beds.

It has already been intimated, that the marine palæozoic formations already noticed are found to lie north of the main Himalayan axis, the great range of crystalline rocks forming the snowy range north of Simla, and terminating apparently in the Dhauladhár. South of this range, resting upon the ancient gneiss in the neighbourhood of Simla, and elsewhere, is a series of schists, quartzites, sandstones, shales, limestones, &c., in which no fossils are known to have been found; some supposed discoveries of mesozoic and tertiary shells amongst these beds having too many elements of doubt to be recognised as authentic. These rocks are known in ascending order as the Infra-Blaini, Blaini, Infra-Król, and Król beds; and they have been supposed by various observers to represent the trans-Himalayan formations in different ways. The most conspicuous band is a massive limestone—the Król limestone of the Simla region. This rock has been traced for a considerable distance both eastward and westward, and was for some time by Dr. Stoliczka supposed to represent the triassic formation of Spiti; but a more probable representative has been recently indicated by Mr. Lydekker in the limestone of the Pir Panjál, believed on fair evidence to be of carboniferous age. If this conclusion be correct, the cis-Himalayan strata of Simla are probably, in part at least, altered palæozoic marine beds; although the absence of fossils, and the great petrological differences from the trans-Himalayan formations, have led to the suggestion, that the Blaini and Król rocks

belong to the peninsular type. No definite connexion with peninsular rocks can, however, be made out.

There is much obscurity attending the relations of the Blaini and Król rocks of the Lower Himalayas to the older gneiss; and in some places, instead of the slaty series resting upon the gneissic formation, the latter appears to overlie the former. There can be little doubt but that such an appearance is illusory, and due to disturbance of later date; in all probability, the Blaini and Król rocks, although of palæozoic age, are much newer than the gneiss, and they are certainly unconformable to it. There appears some reason for inferring that the palæozoic slates, sandstones, and limestones occupy hollows formed by denudation in the old gneissic rocks, and that subsequent pressure has produced the appearance of inversion. If this be a correct view, it is probable that the cis-Himalayan palæozoic rocks are in great part of freshwater origin, and that the present crystalline axis of the Western Himalayas approximately coincides with the shore of the ancient palæozoic continent, of which the Indian Peninsula formed a portion.

Passing eastward along the Himalayas, the whole of the country north of the snowy range is unknown; and it is only possible to infer, from a few marine fossils brought from various parts of Tibet, that there is a continuation in that direction of the Spiti and Kumaun rocks. Along the southern slopes of the Himalayas also, owing to political difficulties, scarcely anything is known of the geology. A possible representative of the Król group is found near Kathmándu in Nepál, and another may perhaps be traced in Bhútan; but the only formation of definite age in this direction is a peninsular rock, the Damúda, to which it will be necessary to refer presently. To the eastward, in Burma, the only fossiliferous palæozoic rock known is the carboniferous limestone of Tenasserim. Devonian rocks are said to have been found in Eastern Tibet.[1]

In the preceding brief survey of our present acquaintance with the azoic and palæozoic formations, it will be seen that, so far as the rocks are known, there is a remarkable divergence between the peninsular and extra-peninsular rocks: a difference so great as to lead to the conclusion, that very different conditions prevailed in the two areas. To this there may have been at first an exception in the case of Burma, where the oldest rocks have not been shewn to be distinct from those of the Peninsula; although, in the newer palæozoic carboniferous times, the sea evidently covered part of the Burmese area; whilst there is no trace of any marine carboniferous formation in the Indian Peninsula.

[1] Comptes Rendues, LVIII, p. 878:—Geol. Mag., I, 1864, p. 76.

At the same time, there is a well-marked distinction between cis-Himalayan and trans-Himalayan formations; the former differing less from the peninsular type than the latter do, and the latter being marine, whereas the former are, in part at least, freshwater. It will be seen that there is the same, or even a greater, contrast from the extra-peninsular formations shewn by the mesozoic and tertiary rocks of the Peninsula, to which it is now necessary to turn.

Gondwana system.—It has already been pointed out, that, in dealing with Indian rocks, it is impossible always to keep to the classification adopted for very different formations in a distant part of Europe. There is good reason for believing that the lowest Gondwána beds of the Peninsula may be of upper palæozoic age; but they are divided by a great break from the next older series, the Vindhyans, whilst they are intimately connected with the Upper Gondwána rocks, which are certainly mesozoic. In returning from the comparison of the extra-peninsular palæozoic rocks to the peninsular area, and in commencing the examination of the Indian mesozoic formations, it is necessary to commence with formations which may represent, in part at least, the upper palæozoic marine beds of the Punjab, the Himalayas, and Burma.

In the Gondwána system organic remains appear for the first time in the Peninsula. But even in these rocks no marine fossils are found in the lower sub-division, all the groups of which consist of sandstone and shale, in some cases with beds of coal, and appear to be of freshwater origin. From a consideration of all the facts known, the approximate age assigned to the Lower Gondwánas is permian and triassic, possibly a little older or a little newer, the evidence being by no means conclusive: the Upper Gondwánas are with more certainty classed as jurassic. The upper sub-division also consists chiefly of sandstones, occasionally associated with clays or marls; and in one instance the beds are interstratified with contemporaneous basaltic lava flows.

The area occupied by the beds of the Gondwána system, although very extensive, is mainly confined to the country between the Narbada and Sôn to the north and the Krishna to the south; and a very large portion of this region to the westward is occupied by newer beds. The only outliers in the Peninsula beyond the limits named are near the east coast, and to the westward in Kattywar, Cutch, and Jesalmir, and consist of Upper Gondwána beds alone; but Lower Gondwánas have been traced for some distance along the base of the Eastern Himalayas.

The Gondwána beds are distributed in large basins, some of which shew a remarkable coincidence with the existing river valleys; and it has hence been inferred that, as the beds are probably of fluviatile origin,

the river valleys of the present day are the same, or nearly the same, as those of the Gondwána period. This conclusion is, however, not admitted by all observers, and must be received with great caution; the distribution of the rocks, in some instances, being quite different from that of the existing drainage areas, and the agreement between the ancient Gondwána basins and the modern river system being perhaps due, where it exists, to the softness of the Gondwána rocks, and to their having in consequence been more easily worn away by rivers. It is a curious circumstance, that the lowest Gondwána beds are singularly constant in character throughout the whole extensive area in which they are found; whilst the difference between the rocks in the different basins is much greater in the higher members of the Lower Gondwána series, and becomes still more marked in the Upper Gondwánas. There are also more marks of local disturbance, sharp dips and faulting, in the Lower Gondwána rocks than in the upper; and it is clear that in some instances the Lower Gondwánas had been tilted and faulted before the Upper Gondwánas were deposited. It is consequently far from improbable that the present Gondwána basins date from Upper Gondwána, not from Lower Gondwána, times. In the Upper Gondwánas, too, there is evidence that the coast line of the Peninsula had begun to assume its present form; for in many places along the east coast, from near Cuttack to Trichinopoly, small patches of Upper Gondwána rocks are found, in several cases interstratified with marine beds, but yet distinctly, in part, shewn to be either of fluviatile, deltaic, or littoral origin, from the coarseness of the materials and the abundance of remains of land plants. In some places, too, as near Ellore, these Upper Gondwána beds of the east coast rest upon a denuded slope partly of gneissic and partly of Lower Gondwána rocks, having the appearance of a plane of marine denudation. Gondwána beds occur near the east coast farther still to the north, close to Cuttack, but no marine beds are associated; and to the north, and north-east no marine jurassic rocks are known to exist. There is consequently no evidence whether the jurassic coast ran farther north in that direction; although, as will be seen, the sea extended much farther in that direction in cretaceous times. Again, to the westward, in Cutch, Upper Gondwána beds are found interstratified with marine rocks of upper jurassic age, and containing the same fossils as the beds on the east coast; the same Upper Gondwána rocks have been traced in Kattywar, and some, probably a little older, occur in the great desert near Jesalmir and Bálmir, where also marine jurassic beds are associated. Now, it is a remarkable fact, that this indication of the ancient coast line is entirely confined to the Upper Gondwána beds; Lower Gond-

wánas being only associated with the upper in a single instance, near Ellore, where the two are quite unconformable, and where the lower series appears to have been planed away, before the deposition of the upper, by the marine denudation to which the slope already mentioned is due. It is only reasonable to conclude, that important changes in the configuration of the country took place in the interval between the Upper and Lower Gondwána periods.

The most marked distinction between the Gondwána basins and the existing river drainage areas is found in the Sátpura region, where the Gondwána rocks form the watershed between the Narbada and Godávari, and do not descend into the main valley of either river; the Gondwána basin of the Godávari itself being quite distinct. In this instance, however, if there had been any coincidence in the former and present river areas, the resemblance could only be due to accident, or to the facilities afforded by the soft Gondwána formations for subaërial denudation, because the whole region in later mesozoic and early tertiary times was covered with a uniform sheet of basaltic lava flows, by which all the ancient features of the country must have been obliterated. It is out of this great sheet of igneous rock that the hills and valleys of Western and Central India have been carved in tertiary and recent times; and amongst the tracts thus exposed by denudation are the Gondwána regions of the Sátpura hills, and, in great part, of the Sôn, Upper Mahánadi and Godávari valleys. Indeed, the vast tracts of Gondwána rocks now exposed in these areas owe their preservation, in all probability, to the protection from denudation afforded by the overlying traps.

In part of Bengal a change in the configuration of the country through the eruption of igneous rocks took place at even an earlier period,—in the Upper Gondwána epoch itself. In the Rájmahál hills, resting unconformably upon the lower Gondwána Damúdas, themselves by no means the uppermost members of the lower sub-division, there is found a band of Upper Gondwána sandstone; and over this again, with slight local unconformity, a great thickness of basaltic lava flows, with interstratified sedimentary beds containing plants. It is not probable that these lava flows were restricted to their present area; and, from the abundance of trap dykes in those Gondwána basins of the Damúda valley which are in the neighbourhood of the Rájmahál hills, and the gradual diminution in the size and number of such dykes as the distance from the hills increases, it is highly probable that part of the Damúda valley was at one time also covered by horizontal traps. Whether this was the case or not, depends upon whether the highest Gondwána beds, referred to the Mahádevas, in the Damúda valley, are older than the

Rájmahál lava flows or newer. If the former, the ground may have been covered with basalt; if the latter, this can scarcely have been the case, as a layer of basalt would have been preserved below the Mahádeva outliers. In favour of the newer age of the Mahádevas, it should be noted, that no trap dyke has been found in them; although such intrusions occur in all Lower Gondwána beds.

So great an outburst of igneous rocks was probably preceded and accompanied by very important changes in the elevation of the neighbouring country; and it is evident that all these changes, and the alteration of the surface by the outburst of traps, must have produced great modifications in the form of the river valleys. Indeed, the manner in which a number of small Lower Gondwána basins, now isolated, but shewing, by the disturbance they have undergone, that their present isolation is due to denudation, are scattered over the country to the west of the Rájmahál hills, indicates the probability that all were once parts of an extensive river valley; and the complete absence of Upper Gondwána rocks in all these small basins may very possibly be due to the breaking up of the river valley in the interim between the Lower and Upper Gondwána periods.

On the eastern side of the Rájmahál hills there is also a possibility that the traps extended across the area now occupied by the upper part of the Ganges delta, and were connected with the stratified traps found north of Sylhet. This is no more than a suggestion; but still the Lower Gondwána land, in all probability, extended to the north-east, as is shewn by the occurrence of Damúda rocks north of Assam; and it is quite possible that the Upper Gondwána terrestrial area may have been continued in the same direction. At the same time, the Sylhet traps may, even if contemporaneous with those of Rájmahál, belong to a different volcanic centre. But the Rájmahál traps shew no signs of thinning out to the eastward, where they disappear beneath the alluvial deposits of the Ganges valley; and it is only reasonable to suppose that they extend for a considerable distance beneath the alluvial covering. Thus, even in Upper Gondwána times, not only is there no reason for supposing that the greatest river valley of India existed, but there is some indication that it had not been formed. As will be shewn presently, there is a probability that the depression of the Gangetic plain, to the eastward at all events, is of tertiary origin.

The very marked difference between the Upper and Lower Gondwána floras, and the connexion that exists between the plants found in the different groups of each of the two major sub-divisions of the system, also point to a break of time of considerable magnitude between the two series.

Physical geography of Gondwana period.—We can thus form some slight conception of the physical geography of India in the Upper Gondwána period. The sea then, as now, occupied the Bay of Bengal, and a portion, at all events, of the Arabian Sea; and large rivers traversed the land then, as now, though not in precisely the same courses. The general form of the southern part of the Peninsula may have agreed more nearly with the present contour than the northern; for the sea occupied the Indian desert and portions of the Punjab and Himalayas. There is not the same clue to the form of the land in the Lower Gondwána period; and all that can be said with certainty is, that the northern part of the Peninsula was a terrestrial area, traversed by great rivers. To the north-east the occurrence of Damúda beds at the base of the Himalayas, in Sikkim and Bhután, may intimate an extension of land in that direction, and a possible connexion with the Chinese area, in which plants allied to those of the Damúda are known to have been found. Such faint indications of the relations between the Damúdas and other Himalayan beds as can be learned from the very obscure mode in which the Gondwána rocks occur in the Eastern Himalayas will be found in Chapter XXV. All the data hitherto ascertained are too imperfect for any conclusions as to age to be based upon them.

Two other subjects of interest remain for notice: the connection with other countries shewn by the fossil flora and fauna of the Gondwána period; and the evidence of climate.

Relations of Gondwana flora and fauna.—The plants of the Lower Gondwánas consist of acrogens and gymnogens; the former, represented by *Equisetaceæ* and ferns, being far more abundant both in species and individuals than the latter, consisting of cycads and conifers. In the Upper Gondwánas the same classes are found; but the proportion is reversed, the conifers, and especially the cycads, being more numerous than the ferns, whilst *Equisetaceæ* are barely represented. The fauna is singularly poor, no animal remains being found in most of the beds; and even plants are scarce in many of the groups. The only formations in which plant remains occur in abundance are the Karharbári, Damúda, and Rájmahál; and even in these the number of species is comparatively far from great.

There are three distinct floras in the Lower Gondwána series: (1) the Tálchir and Karharbári, (2) the Damúda, and (3) the Panchet; and two, besides some intermediate groups, in the Upper Gondwánas: (1) the Rájmahál, and (2) the Jabalpur and Cutch flora. The Tálchir and Karharbári flora has a marked affinity to that of the European Trias, and especially to the Bunter, the lowest sub-division of the Trias; but there is an equally

close connexion with the upper palæozoic (carboniferous) flora in Australia. This resemblance to the Australian carboniferous flora is very much more marked in the next Gondwána group, the Damúda, a considerable proportion of the forms being closely allied, and some being identical; and there is also a close connexion between the Damúda plants and those found in the Karoo series of Southern Africa. Some of the same plants are also found in China; but the details are as yet imperfectly known. On the other hand, the affinity between the Damúda flora and that of any lower mesozoic or palæozoic group in Europe is comparatively small. Some Damuda plants are certainly allied to species found in carboniferous, permian, triassic, and jurassic beds, and perhaps the most marked connexion is with the lower oolites; indeed, the resemblance of a few plants in this case led to both the Damúda beds and the Australian being for a long time classed as jurassic. As will be seen presently, however, there is a very much closer alliance between the plants of the lower oolites and those of the uppermost Gondwána flora; and the latter is divided by an immense thickness of beds and several successive floras from the Damúdas.

Only vestiges of animal remains have been found in the Karharbári and in the typical Damúda beds; but in the Mángli beds, belonging in all probability to the Upper Damúdas, a labyrinthodont skull has been obtained, closely related to a type found, like some Damúda plants, in the South African Karoo beds. In the Panchet group, above the Damúdas, remains of dicynodont reptiles occur, also evincing a connexion with the same South African beds. Two labyrinthodonts, also found in the Panchet beds, are most nearly allied to European triassic forms. Of the four species of Panchet plants known, two are European rhætic species, and the others are allied to rhætic forms, one being, however, nearer to a lower triassic type.

Of the Upper Gondwána floras, the Rájmahál has but little in common with any European assemblage of plants; but it, like the Panchet, is most nearly affined to the rhætic. As between the Rájmahals and Panchets there is the greatest break, both in palæontology and geological sequence, in the whole Gondwána system, the circumstance, that the flora of both is related to that of the same minor sub-division of the European series, shews that too much weight must not be attached to similar cases of affinity in determining age. The Cutch and Jabalpur flora again contains several plants, apparently identical with forms found in lower oolitic (middle jurassic) beds in Europe, the relations, as already stated, being by far the most intimate of any between Gondwána and European fossil floras; but the Cutch beds overlie uppermost jurassic

marine strata, and underlie upper neocomian beds, so that if marine fossils be accepted as a criterion of age, the horizon of these Cutch strata with lower oolitic plants must be very nearly that of the European Wealden. In one of the Upper Gondwána groups, that of Kota-Maleri, found in the Southern Central Provinces, and supposed, on the evidence of a very poor flora, to be intermediate in age between Rájmahál and Jabalpur, a considerable number of ganoid fishes, with distinctly liassic affinities, belonging to the genera *Lepidotus*, *Tetragonolepis*, and *Dapedius*, are found in a bed interstratified with rocks containing teeth of *Ceratodus*, and remains of two reptiles, *Hyperodapedon* and *Parasuchus*—all characteristic triassic forms. The contradictions as to age of the Gondwána fauna and flora are thus very great, so long as these beds are compared with the European sequence. As a general rule, in the Upper Gondwánas all the forms appear to have lived at a later period than in Europe; but in the Lower Gondwánas the reverse is the case. The Rájmahál beds are very possibly not quite so old as rhætic. There is much probability that the Kota-Maleri group is newer than liassic, and it is certainly of later age than the trias; the Umia group of Cutch is clearly posterior in date to the lower oolite, whilst, on the other hand, amongst the Lower Gondwána formations, the Karharbáris are probably older than triassic; the Damúdas are certainly of pre-jurassic age, and the Panchets may very possibly, although triassic, represent a somewhat earlier period than that of the rhætic group.

It would of course be equally unsafe to insist upon the affinities of the Karharbári, Damúda, and Rájmahál floras, and of the Mángli and Panchet faunas, with those of various beds in South Africa and Australia, as proving contemporaneous age. But the very marked affinities between the different terrestrial forms of plants and animals in the rocks of these distant regions may be fairly assumed to shew that there was at times, if not continuously, land connexion between the two countries. In the Lower Gondwánas the relations with the Australian forms of life are stronger than with the European. Whilst the Damúda flora exhibits the most marked relationship to that found in beds intercalated with marine carboniferous rocks, or conformably overlying them, in Australia, neither the Australian nor the Damúda plants have any resemblance to those found in the coal-measures of Europe; although the latter occur in beds having precisely the same relations to the carboniferous mountain limestone as the Australian rocks have to the marine beds with mountain limestone fossils. It is reasonable to infer that at this period, or soon after, India was united with Australia by land, but not with Europe, and that the latter connexion took place later. Hence the occurrence of such Lower Gondwána types as are found in European beds in rocks of

later date in the last-named area: for instance, the genus *Phyllotheca*, found in the carboniferous beds of Australia and the Damúdas of India, but not in any formation older than jurassic in Europe. It is not improbable that the Lower Gondwánas of India are of intermediate age between the carboniferous of Australia and the trias of Europe.

Above the Lower Gondwánas the evidence of connexion with Australia is faint; and where any exists, it is perhaps, on the whole, in favour of a passage from India towards Australia. Thus the genus *Ceratodus* of the Indian Upper Gondwánas is represented by living freshwater fishes in Australia; and *Hyperodapedon* is most nearly related among recent lacertians to the New Zealand *Hatteria*. Such affinities, however, are of minor moment. In the case of Africa, the land connexion appears to have been more permanent, and it may have existed continuously to tertiary times. Some evidence on this point will be mentioned hereafter.

Some of the plants common to the Cutch or Jabalpur beds and the lower oolitic or middle jurassic rocks of Europe have also been found in parts of Eastern Europe and Western and Northern Asia; so that there is abundant evidence of this flora having been widely diffused in the northern hemisphere. Unfortunately the age of the rocks containing the plants appears in the majority of cases to have been inferred from the flora; and as this has been shewn to be insufficient evidence in India, it is impossible to tell whether the rocks at the various localities in South-Eastern Russia, the Caucasus, Northern Persia, Siberia, Northern China, and Japan, at which plants resembling those of the lower oolites have been found, are of contemporaneous origin; or whether they are intermediate in age between the middle jurassic beds of Western Europe and the upper jurassics or Wealden of Western India. It is fair to infer that the countries were connected by land during a portion of the intervening period; but it is quite uncertain how far the union was permanent, or to tell whether it still existed in upper jurassic times. It appears probable that the sea extended to the westward far north of Cutch; but there are some remarkable differences between the jurassic rocks of Cutch and those of the Himalayas; and these differences may have been due to a land barrier between the two regions.

Climate of Gondwana epoch.—The climatological evidence contained in the Gondwána rocks is very curious; and although it cannot be said to prove an epoch of low temperature, it certainly suggests it. In the Tálchir formation, almost wherever that extensively developed group is exposed, fragments of metamorphic, transition, or Vindhyan rocks are found imbedded. These fragments are always rounded, often of large size (many having been measured 6 feet in diameter, and some are pro-

bably larger), and in many cases imbedded in the finest silt. It is difficult to understand how such large blocks can have been transported and deposited in a fine mud without the agency of ice: roots of trees are out of the question where the occurrence is on so large a scale. In one instance, moreover, some of the blocks were found to be polished and striated, and the underlying Vindhyan rocks were similarly marked. The appearances are not such as would be produced by glaciers; and it appears more probable that if ice transported the blocks, it was in the fluviatile form known as ground ice. It was at first suggested that this might be the case without any change in the temperature, as the Talchir formation might have been deposited on a plateau sufficiently lofty for ground ice to be formed. But the additional evidence since obtained of similar deposits, apparently of glacial origin, in South Africa, in beds precisely corresponding to the Talchirs in position, the likelihood that the Permian breccias of England are also glacial, the poverty of the Permian fauna, and the great break in forms of life at the close of the palæozoic period, together with the additional astronomical data in favour of variation in the sun's heat—all combine to suggest the possibility of recurrent epochs of diminished temperature having taken place at intervals in the earth's history, and of one of these intervals having coincided with the Permian epoch. This might perhaps also explain the migration of Australian and African plants to the tropics, and the subsequent dissemination of these same plants in the temperate regions of Europe and Asia, as the earth's temperature increased again. There is nothing in the Lower Gondwána flora to indicate tropical affinities: the flora, as already noted, is poor, and the ferns might as well have inhabited a damp temperate climate as a tropical one; whilst the beds containing the Talchir boulders are singularly devoid of life, either vegetable or animal.

It should here be noticed that two cases of large boulders imbedded in a fine matrix are known in India amongst earlier rocks, and one at least in a later formation. One of these was in some transition beds, of unknown relations,[1] resting upon Maláni volcanic rocks near Pokran, between Jodhpur and Jesalmir, in Rájputána. Here also a striation of the underlying formation was observed. The second case is in the Himalayas of Pángi, south-east of Kashmir. Here the old slates, supposed to be silurian, contain boulders in great numbers. The third instance was in the Salt Range, where blocks of great size are imbedded in a clay supposed to be of upper cretaceous age; and one of the boulders was found to be polished and striated in a very characteristic manner on three different faces.

[1] Rec. G. S. I., X, p. 13. The notice of this boulder bed has been omitted in Chapter II of this work.

Another method of accounting for the difference of temperature in past times is that noticed a few pages back, when the absence of life in the Vindhyan rocks was mentioned—a possible change in the direction of the earth's axis. Whether such a change can have taken place is a question that may be left to astronomers and mathematicians, and that appears as yet to be by no means decided. So far as the climate of India in past times is concerned, granting, as appears probable, that a lower temperature prevailed in certain past epochs, either a secular refrigeration or a change in the earth's axis would equally account for the deficiency of heat. It is extremely doubtful, however, whether any change in the relative positions of the earth's surface could satisfactorily account for the recent glacial epoch, of which, as will be seen, the effects were probably felt in India; and if a cool temperature prevailed in the Permian period, it is highly probable that it was due to the same cause as in pleistocene times.

Jurassic marine rocks.—The marine zones associated with the Upper Gondwána beds of the east coast have not, with one exception, been accurately determined; but few characteristic forms of fossils occur, and the majority of the species found have not been determined. The exception is the highest marine bed known, in which forms of *Trigonia*, *T. ventricosa*, and *T. smeei*, have been found, characteristic of the higher or Umia beds in Cutch. The Cutch jurassics afford a very complete representation of all the European jurassic beds above the inferior oolite; the Bath, Kelloway, Oxford, Kimmeridge, and Portland faunas being more or less clearly distinguished. No equally full sequence of marine jurassic beds is known to the northward in the extra-peninsular area, but the upper jurassics are, as will presently be shewn, represented in the Punjab and the Himalayas. North of Cutch also, in several parts of the desert country between the Indus and the Arvali mountains, jurassic rocks are found, the best known being, perhaps, some near Jesalmir, of Oxford or Kelloway age: with these, as already mentioned, are associated beds apparently of freshwater or littoral origin, and containing obscure remains of terrestrial plants and fossil wood. It is probable that the jurassic coast line of the Peninsula ran northward from Cutch through Western Rájputána to the Salt Range of the Punjab, where also marine jurassic rocks containing plant remains are found, but are restricted, like carboniferous and triassic marine formations, to the western part of the range.

The highest jurassic group in Cutch, that of Umia, contains at the base a marine fauna, with several species of mollusca common to the Portland zone of the European oolites, and also some forms, amongst

which two *Trigoniæ*, *T. ventricosa* and *T. vau*, are conspicuous, characteristic of certain very high jurassic beds in Southern Africa. The plants identical with forms found in the inferior oolite beds of Europe occur at a rather higher horizon; but there is some intercalation of marine fossils above the plant beds. Above the whole, whether conformably or not is uncertain, is a thin band with upper neocomian *Cephalopoda*; and this is succeeded by Deccan trap, the last-named formation being unconformable to the underlying beds.

Cretaceous marine beds.—No association of upper cretaceous beds with the marine jurassic rocks has hitherto been clearly traced on the eastern shores of the Peninsula; although some fossils, which may belong to a very high cretaceous horizon, occur at the base of the traps near Rájámahendri (Rajamundry) and Ellore, overlying beds, believed to be identical with those containing *Trigonia smeei* and *T. ventricosa* a little farther to the north-east; and some cretaceous mollusca have been brought from Sripermatur, west of Madras, where, however, the relations of the rocks containing them to the beds with marine remains in the Sripermatur Upper Gondwána beds are very obscure. By far the most important cretaceous deposits of India are those of the neighbourhood of Pondicherry and Trichinopoly, where a series of marine fossiliferous strata, classed in ascending order as the Utatúr, Trichinopoly, and Arialúr groups, correspond in age to the European cretaceous beds, from Upper Greensand or Cenomanian to Upper Chalk or Senonian inclusive. The uppermost strata of the Arialúr group may possibly represent a still higher horizon; but they have not been definitely distinguished. The lowest group or Utatúr rests in places, with slight unconformity, on Upper Gondwána beds, apparently, to judge by the flora, of an age intermediate between Rájmahál and Jabalpur, and elsewhere upon the gneiss: at the base of the Utatúr group there is frequently a great coral reef. Great unconformity exists between the Utatúr and Trichinopoly groups, and some may also occur between the Trichinopoly and Arialúr; but it is chiefly shewn in the latter case by overlap.

All the groups are in part or wholly of littoral origin; none appear to be deep-water deposits. Fossil wood is found abundantly in the two higher groups; and there is evidence of a tract of land north of Trichinopoly having been elevated above the sea and brought under the influence of denudation in the interval between the Utatúr and Trichinopoly groups. Everything combines to suggest that the eastern coast line of Southern India in upper cretaceous times was but a few miles farther west than it is now, and that the general direction was the same. The occurrence of marine beds at the base of the traps near

Rájámahendri and Ellore, although the geological horizon is not quite certain, and may be later than that of the Arialúr beds, tends to indicate the continuance of the same coast line. Again, in the Khási and Gáro hills, and throughout a great part of the Assam range, marine cretaceous beds occur, containing in large numbers the same fossils as the rocks of Trichinopoly, and probably deposited in the same sea, and very possibly on the same line of coast. There is, however, a break between Ellore and the Gáro hills; and there is not the slightest indication of marine conditions in cretaceous times in the Ganges valley. Marine cretaceous beds occur also in Burma; but only one fossil, an ammonite (a Trichinopoly species) has hitherto been procured from them.

Similar fossils are not found elsewhere in India; but in South Africa there is again, as in the Gondwána and marine jurassic beds, a singularly close connexion with the rocks of Southern India. In some marine cretaceous strata of Natal, the majority of the fossils found are identical with those of the Trichinopoly formations. As the fossils are chiefly shallow-water and littoral forms, it appears a probable conclusion, that a line of coast extended in cretaceous times from India to South Africa.

Distribution of cretaceous land.—From the remains found in another part of India, some farther indication is afforded of the distribution of land in the upper cretaceous period. In the Narbada valley here and there, from Barwaha (Barwai) to the neighbourhood of Baroda, some poorly fossiliferous sandstones and limestones are found at the base of the Deccan traps; and near Bágh, a band containing a rather better series of fossils has been discovered in a bed associated with these sandstones. The fossils are characteristically of Upper Greensand (Cenomanian) age, the same as the Utatúr group; but only one species out of eight or nine well-identified forms from the Bágh beds is common to the rocks of Southern India, and this species, *Pecten* (*Vola*) *quinquecostata*, is one of the most widely spread of cretaceous fossils, and is represented by distinct varieties in the Narbada valley and near Trichinopoly. But whilst there is thus a wide difference between the fossils of the Bágh beds and those of the probably contemporaneous strata in Southern India, there is precisely the same resemblance between the Bágh fauna and that of certain beds of the European Upper Greensand, as there is between the South Indian cretaceous deposits and those of South Africa : the Bágh fauna being also found represented in Southern Arabia. It has already been shewn that a coast line probably extended from India to Southern Africa, and it does not appear an unreasonable inference that this coast may have been the southern shore of a land barrier separating the seas

of Europe, Arabia, and Western India from those in which the deposits of the Assam hills, Trichinopoly, and Natal were accumulated. There was thus very probably in cretaceous times the same union with Africa as already indicated in the later palæozoic and older mesozoic period, and the same coast line along the eastern shore of the Indian Peninsula as in the jurassic epoch, but perhaps extending much farther to the north-east. In cretaceous times, as in earlier mesozoic periods, there is no indication of any deposits having taken place in the Ganges valley; and the absence of any mesozoic beds between the tertiaries of the Sub-Himalayas and the ancient rocks of the mountains is rather opposed to any large accumulation of strata, either subaërial or aqueous, having been formed, in the intervening epochs, within the area of the Gangetic plain.

The number of species common to the whole cretaceous fauna of Southern India and that of Europe is 16 per cent.; but the proportion varies in the different groups, being greatest in the Utatúr, 18 per cent., and least in the Arialúr, 12 per cent.; those species only being taken into calculation which are in India peculiar to each group. In the Trichinopoly group the percentage of European species is 15. The gradual diminution in the number of common species may mark the effects of a long-continued period during which the European seas were only in indirect communication, probably by a circuitous route, with those of India; the direct communication having been cut off after the latest jurassic times, when the connexion between the areas was shewn by the same species (*Trigonia ventricosa*, &c.) occurring on both coasts of India. The resemblance of the South Indian to the European cretaceous fauna is greatest in *Cephalopoda*, *Brachiopoda*, and *Echinodermata*, and is much less marked in *Gasteropoda*, *Lamellibranchiata*, *Bryozoa*, and corals. The representation of zones in Europe by the corresponding sub-divisions in India is, however, much less close than in the jurassic rocks of Cutch—a circumstance which also tends to indicate less direct communication between the seas. In the *Cephalopoda*, on which alone the comparison of the Cutch jurassics is founded, this irregularity is especially marked; Neocomian species being found throughout the South Indian upper cretaceous series, and the whole facies of the Utatúr *Cephalopoda*, amongst which no less than 25 per cent. are common to European deposits, agreeing better with the Gault than with the Upper Greensand fauna. The Utatúr group, it should be added, contains no less than 109 out of the 146 species of *Cephalopoda* found in the South Indian cretaceous deposits. Some South Indian cretaceous forms, too, are allied to European jurassic types; and three species belong to a section of *Ammonites* not found in

Europe in higher beds than the trias. Again, amongst the *Gasteropoda*, and especially in the upper or Arialúr group, a large number of tertiary and recent genera are represented.

Deccan traps.—Whilst the upper cretaceous beds were being deposited on the south-eastern coast of India, the volcanic outbursts of the Deccan traps must in all probability have commenced. These rocks form one of the grandest masses of bedded traps to be found in the world, and present several very interesting problems. The Deccan traps consist of a great series of basaltic lava flows, for the most part assuming the form of basalt; all either nearly horizontal, or presenting the appearance of having been so originally. They possess a vertical thickness of between 4,000 and 5,000 feet in some of the Sahyádri scarps, and probably where thickest amount to 6,000 feet at least; and they cover an area roughly estimated at 200,000 square miles, and in all probability originally very much greater. These basalts thin out towards the extremity of the area, but they are traced from Sind to Chutia Nágpúr, and from Belgaum to north of Goona, or throughout 16 degrees of longitude and 9½ of latitude.

The absolute geological date of these igneous eruptions is difficult to fix, and they may have continued to be poured out during a long period. It has been suggested by some geologists that the Rájmahál traps of the Upper Gondwána period and the Deccan traps are portions of one continuous series of outbursts. This is one of those suggestions which are difficult of proof or disproof for want of evidence as to the precise geological horizon of the uppermost traps in the Rájmahál hills; but there is no known connexion between the two series of lava flows. Each is limited to a definite and separate area; for there is no reason to suppose that the Deccan traps ever extended beyond the western part of Chutia Nágpúr, whilst the most western dykes referable to the Rájmahál period are 100 miles farther east. It is not probable that the beds containing the Rájmahál fossil flora can be much newer than middle jurassic, whilst the oldest of the Deccan traps are clearly not older than upper cretaceous; and if the outbursts are supposed to be continuous, it must be inferred that the 2,000 feet of Rájmahál traps represent the accumulations of a period extending from jurassic to upper cretaceous, whilst the whole 6,000 feet or more of Deccan traps were poured out between upper cretaceous and lower eocene times. If the Sylhet traps are really contemporaneous with the Rájmahál, as is by no means improbable, continuity between the Rájmahál and Deccan trap periods is out of the question; for the Sylhet lava flows are overlain unconformably by cretaceous rocks of about the same age (Cenomanian) as those underlying the oldest Deccan

traps; but it is not quite certain that the Sylhet trap is of the same age as the Rájmahál; and even if the two belong to the same period, the uppermost Rájmahál lava flows might be of later date than those in the same relative position in Sylhet.

There is but little petrological distinction between the traps of Rájmahál and those of the Deccan; both consist chiefly of basalts, both are composed of nearly horizontal beds, and both, as will be shewn presently, are of subaërial origin; but in the absence of any direct evidence, it is premature to suggest that there is any connexion between the two formations, or to class them as portions of one great igneous series.

The oldest of the Deccan traps are slightly unconformable to the cretaceous (Cenomanian) rocks of Bágh, whilst middle eocene beds rest with complete unconformity upon the denuded surface of the upper trap beds in Guzerat; and in Sind one thin band of trap, evidently representative of part of the Deccan series, is intercalated between very high cretaceous and very low eocene beds; whilst another band of trap, also apparently of contemporaneous origin, occurs interstratified with upper cretaceous beds several hundred feet below the upper band. The older traps are consequently classed as upper cretaceous; but it is far from improbable that the uppermost beds may be of the earliest eocene age, and that the traps may represent the whole intervening period between cretaceous and tertiary.

The Deccan traps have been very generally considered tertiary, chiefly on the evidence of the freshwater shells in some of the intertrappean beds; but these shells, as will be shewn in subsequent pages, have not been quite correctly determined, and the stratigraphical evidence is intrinsically of more importance, besides being better established.

In the Narbada valley, where the Deccan traps rest upon the marine cretaceous beds of Bágh, there is a peculiarity about the very slight unconformity between the two formations, characteristic of subaërial denudation; and there appears no reasonable doubt that the Bágh beds had been elevated above the sea before they were covered by the lava flows of the Deccan period. Elsewhere at the base of the traps either freshwater beds, known as Lametas, are found, or the basalt rests upon a worn surface, evidently terrestrial, of metamorphic, transition, or Vindhyan rocks. The Lametas are a thin band, closely resembling the Bágh beds in mineral character, and possibly a freshwater representative of them. With the lowest traps of Central India, almost all round the outer limit of the trap area from Cutch through Rájputána and the Central Provinces to the Southern Mahratta Country, freshwater beds, apparently of lacustrine origin, are interstratified; and in these beds numerous freshwater mollusca

and remains of terrestrial plants, with a few insects, small crustacea, and fish, are found. In some few places coarser deposits, evidently transported by rivers, and containing rounded fragments derived from the underlying traps themselves, as well as from older rocks, are met with. All these deposits clearly prove that the lower traps were poured out on a land surface; and amongst the very highest lava flows of Bombay, 6,000 feet or more above the horizon of the Central Indian beds, freshwater deposits are again found, also teeming with life, both vegetable and animal, and affording evidence of terrestrial conditions. There are also found, in many parts of the trap area, thick beds of volcanic breccia, evidently of subaërial formation; for they want the stratified arrangement characteristic of subaqueous deposits. A few laminated ash-beds may have accumulated in lakes.

Despite the fact that the uppermost and lowermost beds are thus demonstrated to be subaërial, that many intermediate layers are also proved not to be of subaqueous origin, and that there is no structural difference between the beds shewn to be subaërial and the remainder of the series, it is still contended by some geologists that the Deccan traps must be submarine. This view was originally advanced before the data now ascertained were known; but the idea has not been entirely abandoned, even since it has been proved that a part at least of the lava flows must have been poured out on a land surface. The great distinction between all such horizontal bedded traps as those of the Deccan and the lava flows of modern volcanoes, and the enormous distance to which the trap flows must have been extended from the point of eruption, are characters not yet explained; but a favourite theory with some geologists, that such flows must have been submarine, because a lava flow would preserve its heat and fluidity longer under the pressure of a large volume of water than in the air, is not only unproved, but is opposed to the known properties of water. Moreover, submarine volcanic rocks are common in the older formations, and are very different in character from such rocks as the Deccan traps. All such subaqueous accumulations are interstratified with ordinary sediment, and so closely intermixed, that it is often difficult to tell whether they are really of igneous origin or not. Such are the trappoid beds of the Indian transition rocks. Now, in no single instance have rocks of this kind been detected in the Deccan trap series; on the other hand, the structure of the beds from top to bottom is that of ordinary subaërial lava flows. It may fairly be concluded that all such bedded traps as those of the Deccan and the Rájmahál hills are of subaërial origin.

Although the Deccan traps occasionally overlie or underlie marine deposits, there is almost always distinct unconformity between the two;

and there are but two localities, in very distant parts of India, where any *interstratification* of marine beds with igneous rocks has been detected. These cases of interstratification are, however, the sole clue afforded to the outline of the Indian continent in the Deccan trap period. The one has been already noticed as taking place in Sind; the other is at Rájámahendri. In both instances the trap is probably littoral, if not truly subaërial; in Sind, coarse beds, conglomerates, and sandstones are associated with the lower band of trap, whilst immediately over the upper layer, sandstones, apparently of freshwater, and probably of fluviatile origin, are found. Near Rájámahendri the bottom flow of basalt rests upon a marine stratum, and is overlain by a band containing estuarine fossils, followed by a second lava flow. The latter locality may intimate a continuance of the general line of coast that has been shewn to have existed in upper jurassic and cretaceous times, and that remains to the present day.

The Rájámahendri traps may possibly be part of a distinct outburst, as no lava flows are preserved in any portion of the interval, 210 miles in length, between Rájámahendri and the main trap area in the Godávari valley. In all probability, the limit of the trap outliers in Rájputána, the Vindhyan table-land, Chutia Nágpúr, and the Southern Mahratta Country nearly corresponds with the original boundary of the region covered with igneous rocks; for just beyond the limit laterite is found in many places resting directly on the older rocks; and the laterite appears, as will presently be seen, to be of but little later date than the highest traps. But along the Bombay coast the traps disappear beneath the sea, where they are at their greatest development; and, in consequence of their westwardly dip, the rocks seen on the coast are the highest known. How far the igneous rocks of the Deccan period extend in this direction, it is impossible to say, but probably for a considerable distance; for some of the great centres of eruption, to judge by the prevalence of dykes and similar intrusions, were in the neighbourhood of the west coast. It is probable also that the land in the Deccan trap period extended for a long distance to the westward.

Another circumstance, tending to indicate that the approximate limit of the area covered by the traps in India is shewn by the outliers, is, that throughout the circuit of the igneous rocks, from Rájputána, *viâ* Chutia Nágpúr, to the neighbourhood of Belgaum, trap dykes are rare or wanting; whilst in parts of the Narbada valley, in the Konkan north of Bombay, in Guzerat and Cutch, dykes and other intrusions abound. Many of these intrusive masses are of large dimensions, sometimes miles in diameter; and they doubtless fill the channels through which the eruptive rocks reached the surface. It is probable that the Deccan

traps flowed from vents without the formation of volcanic cones, as no traces of the inclined beds of such cones have been found; and the distinction may have been due to the greater fluidity and larger mass of ejected lava, and to its consequently increased power of transporting all the materials brought to the surface by igneous agency to a much greater distance from the point of emission.

High-level laterite.—It is evident that the close of the volcanic outbursts left all the surface of Western India a huge plain of basaltic rock, the plain which later denudation has carved into the hills and valleys of the Peninsula. The only formation superposed upon the basalt throughout the greater part of the area, with the exception of gravels and clays of late tertiary or subrecent date, is the high-level laterite, or iron clay, a ferruginous and argillaceous rock, from 30 or 40 to 200 feet thick, capping the summit of many of the highest trap plateaus, and also occurring on other rocks, beyond the limits of the trap area, in such a manner as to shew that the caps now remaining are merely isolated fragments of a bed once far more extensive. This bed probably covered a large portion of the trap area and the neighbouring regions, and perhaps extended throughout the greater portion of Peninsular India. Nor is this all. In the nummulitic beds of Guzerat, Cutch, Sind, and the Salt Range of the Punjab, and in the Subáthu beds of the Sub-Himalayas, all of middle eocene age, there are found one or more beds of ferruginous rocks absolutely undistinguishable from laterite, and probably, from their wide extent, of contemporaneous origin.

In many places the laterite bed passes into the uppermost traps, and hence it has been very naturally inferred, that laterite is merely an altered form of the basaltic rock itself; but it appears most probable that decomposed basalt, when iron peroxide is added, forms laterite, and that consequently passage from the one into the other is natural; but that the high-level laterite bed is really throughout of detrital origin, as it is proved to be in places by containing pebbles and sand. It probably consists of altered volcanic detritus, perhaps of scoriæ and lapilli; the excess of iron being either due to the ferruginous nature of the volcanic outbursts, or to a process of washing by which the lighter, less ferruginous matters were carried farther away from the original source of the materials, and formed deposits less easily consolidated, and, in consequence, more easily destroyed by denuding agencies. Other laterite formations, deposited after much denudation of the traps had taken place, and found at low levels in various parts of India, may have been derived, in some cases at least, from materials provided by the denudation of the high-level form.

Tertiary coasts of Peninsula.—With the high-level laterite the sequence of older rocks in the peninsular area of India may be considered to close, late tertiary and recent deposits alone remaining, except in a few places on the coast. It will now be necessary to return to the extra-peninsular areas, and to see what was their history in mesozoic and early tertiary times, so far as a record is preserved by the rocks, whilst the Peninsula, as has been shewn, was a land area, as it is now. It should be first stated that the tertiary rocks around the coasts of the Peninsula afford but a faint indication of the distribution of land and sea in tertiary times. No marine beds of later date than cretaceous are known on the east coast, and the only tertiary beds are the Cuddalore sandstones of uncertain date and origin; whilst on the west coast the sea certainly covered a portion of Guzerat in eocene and miocene times, the coast lines being perhaps not very different from what they are now, although the sea extended some distance in what is now an inland direction. To the south, in Travancore, for the first time in geological history, we find that a marine deposit was formed in the miocene age; and we may perhaps infer that the southern portion of the western coast then first assumed something resembling its present outline. When treating the probable inferences to be drawn from the Indian fauna as to the former connexion between India and other countries, it will be seen that India may have been directly connected with Africa till the middle of the tertiary period.

Extra-peninsular mesozoic rocks.—The mesozoic history of the extra-peninsular tracts is even more meagre than is that of the peninsular area. Of triassic rocks no trace is known in Sind, none of the formations of that province being of older date than cretaceous; but it is highly probable that triassic strata may exist near Kelát in Baluchistan, as *Ceratites* and *Orthoceratites* have been obtained there. Ceratite beds, probably of Bunter or lower triassic date, are found in the western part of the Salt Range of the Punjab, and in some of the ranges west of the Indus near Isakhel (Esakhel), but have not been clearly shewn to occur elsewhere; although representative beds may possibly be found in the Himalayas. The overlying beds in the Salt Range are poorly fossiliferous. In Hazára, the upper triassic or rhætic beds with *Megalodon* and *Dicerocardium* alone contain distinctive fossils, the underlying strata being destitute of organic remains; whilst the next beds in ascending order, though probably of rhætic age, contain no characteristic forms. In Northern Kashmir, and throughout the mountain region to the south-east as far as Spiti, and probably farther, resting upon the carboniferous rocks, there is a well-developed series of triassic

beds, commencing at the base, where best known and exposed, in Spiti, with a band of limestone, abounding in *Halobia lommeli*, and resting upon carboniferous beds with *Spirifer keilhavii* and *Productus semireticulatus*. Above the *Halobia* band are beds of concretionary limestone with numerous fossils, many of them similar to those of the upper trias (Hallstädt and St. Cassian) in the Alps. These Himalayan rocks are the Liláng series of Stoliczka, and in places exceed 2,000 feet in thickness. They were classed by Stoliczka himself as upper triassic, or Keuper; but other writers are inclined to consider them more probably of middle triassic age. The next formation in ascending order, the Pára limestone, some hundreds of feet thick, contains *Dicerocardium himalayense* and *Megalodon triqueter*, the latter characteristic of the Dachstein limestone in the Austrian Alps; and above the Pára limestone is the Tagling limestone, 2,000 feet thick, and containing in its lower beds fossils characteristic of the Kossen beds, the characteristic rhætic formation or *Avicula contorta* zone of the Alps, and in its uppermost strata several forms typical of the Alpine liassic beds of Hierlatz.

To the eastward, marine triassic rocks have only been detected in Burma, where *Halobia lommeli* has been found. This, however, is a species of almost world-wide distribution, and consequently of but small value as evidence of any exact horizon. It is impossible to found on this isolated occurrence any conclusions as to the triassic seas of the Burmese area being connected or unconnected with those of the North-West Himalayas.

The triassic and rhætic beds of Western Tibet and the North-West Himalayas are found represented as far north as the Mustágh Range; and the upper triassic beds are widely developed to the northward of the Kuenlun, in the mountains to the north and west of Eastern Turkestan.

A remarkable peculiarity in the triassic fauna of the North-West Himalayas, or rather of Western Tibet (for the area of Spiti, Zánskár, &c., is trans-Himalayan, and inhabited by Tibetans), is the similarity of the fauna throughout the whole series to that of the corresponding beds in the Alps. It is true that the sub-divisions of the strata do not always precisely correspond; but the community of specific forms is such as to render it highly probable that the seas of the two areas must have been united throughout the period. But, at the same time, some land connexion between India and Europe is indicated by the appearance of Karharbári plants in the European lower triassic, and of Panchet species in the rhætic. It is difficult to say whether the trias of the Salt Range was deposited in a different sea from that of Hazára, Káshmir, and Spiti; but the fossiliferous Salt Range beds appear to be older, and the absence of any lower triassic strata between the *Halobia* limestone and the

carboniferous Kuling series, together with the non-appearance of the characteristic upper triassic and rhætic fossils in the Salt Range, although some of them are found in Hazára, and perhaps farther to the westward, may indicate a distinction between the marine areas.

Except in the upper beds of the Tagling limestone, no representatives of the true liassic fauna are known to occur in the neighbourhood of India. The extra-peninsular jurassic formations, although more extensively developed than the triassic, are only known with certainty to exist in the Western Himalayan and Tibetan area and in the Punjab. Jurassic *Cephalopoda*, as well as triassic and cretaceous forms, are said to have been brought from Kelát. The jurassic rocks of the Salt Range have already been noticed in connexion with the closely allied and better developed series in Cutch; and it was shewn how the oolitic formations of the two areas were connected by outcrops in the deserts of Western Rájputána, and were doubtless deposited in parts of the same sea. The upper jurassic rocks of Hazára are more closely connected with those of Spiti.

Above the rhætic and liassic Tagling limestone in Spiti, some slaty beds, with fragments of *Belemnites*, a *Posidonomya*, and other ill-marked fossil forms, occur, and then black, friable shales, with calcareous concretions. These, the Spiti shales of Stoliczka's classification, are generally 200 to 300, rarely 500, feet in thickness, and abound in fossils, especially *Ammonites*. The fauna was classed as middle jurassic (lower to middle oolitic) by Stoliczka; but his views have since been questioned, and it now appears more probable that most of the fossils are upper jurassic (Kimmeridge and Portland); though it yet remains to be seen whether distinct zones can be traced. If they can, some may be older. Above the Spiti shales, the Gieumal sandstone, 200 to 600 feet thick, is found, and consists chiefly of a pale-coloured grit, poor in fossils. The few mollusca that occur are mostly ill-preserved and uncharacteristic bivalves.

To the eastward the jurassic rocks are traced for some distance, being found in Ngári-Khorsum, and probably much farther in Tibet; and it is said that *Ammonites* of the same species as those of Spiti are brought from the neighbourhood of Lhassa. North of the Indus, however, and in Northern Kashmir, jurassic beds do not occur. In the Northern Punjab, representatives of both the Spiti shales and the Gieumal sandstone, possessing the same mineral characters as in Spiti, reappear in Hazára, and are traced to the westward, where, however, they lose their distinctive mineral characters.

Although the fauna of the Spiti shales is believed to indicate the same upper jurassic age as that of the Katrol and Umia beds of Cutch, there is but little resemblance in the fauna. Only five species of Hima-

layan jurassic *Cephalopoda* are recognised by Dr. Waagen as identical with those of the Cutch beds; and even of these, one is a species found only in a lower sub-division in Cutch. Whilst numerous Central and Western European forms are found in the Cutch beds, only one such species is known from the Spiti shales, several, at first referred to European species, having since been considered distinct. On the other hand, there is some similarity of facies between the Spiti shales fauna and that of the Russian oolite. The Spiti jurassics occupy an elliptical tract, extending to the west-north-west as far as Zánskár; but doubtless owing its present restricted area in great part to denudation, as outliers occur to the eastward.

The characteristic *Trigoniæ* of the Umia beds of Cutch are found in beds representative of the Gieumal sandstone in Southern Hazára. It may be remembered that these same *Trigoniæ* are also found in the uppermost jurassic beds on the east coast of the Indian Peninsula, where the few marine fossils occurring in the jurassic Upper Gondwána beds at a lower horizon appear different from those of Cutch. This wide dispersal of a similar fauna at the close of the jurassic period may indicate depression of land and a free communication between the seas, in which the marine beds of the east and west peninsular coasts, the Punjab and Spiti, were deposited. It is possible that about this time the direct land communication with Africa was broken up into islands; though, as has already been shewn, the connexion was probably re-established in cretaceous times.

The cretaceous rocks of the extra-peninsular regions to the east and south-east, in Assam and Burma, have already been noticed: those to the west and north-west are too few and scattered to furnish much information. Doubtless, the greater portion of the cretaceous marine deposits are concealed beneath tertiary formations. Neocomian beds have been found in the western continuation of the Salt Range, beyond the Indus; upper neocomian or Aptian, as already noticed, in Cutch; gault in Hazára, and some beds of uncertain age near Kohát. Upper cretaceous beds, in the form of hippuritic limestone, occupy an enormous area in Persia, and were very possibly originally continuous with similar rocks in Southern Europe. It is not known how far this formation extends in the direction of India. Cretaceous rocks are well developed around Kelát and in some other parts of Baluchistan, and in all probability occupy a large area just west of the British frontier; but no details have been ascertained as to the sub-divisions represented. Away to the northward in Spiti, and again still farther north beyond Chángchenmo, on the frontier of Khoten, beds containing hippurites have been detected,

those in Spiti being the Chikkim beds of Stoliczka; and in Lower Sind at one locality a hippurite has been found in a limestone, the lowest bed exposed; but the Himalayan beds are merely fragmentary outliers, left on the top of hills, and the Sind exposure is a small inlier, seen in one spot only. Above the limestone in the last-named locality are the coarse sandstones, in which, as already mentioned, a flow of Deccan trap is intercalated; and to the sandstones succeed some soft olive-coloured shales and sandstones containing *Cardita beaumonti* and other fossils, and capped by the highest trap-flow. These sandstones and olive shales are of a very high cretaceous horizon, and are doubtless littoral beds. Similar strata are found in the Salt Range of the Punjab; but in a section examined to the west of the Sind frontier both the olive beds and the trap were wanting. It is very probable that the eastern shore of the upper cretaceous sea passed from Sind to the Salt Range and then northward; but the data are very imperfect. Far away to the north-east in Tibet, and to the west of Lhassa, a species of *Glauconia* (or *Omphalia*) has been found, which may indicate the existence of upper cretaceous beds, probably littoral or estuarine.

Tertiary rocks.—The eocene rocks afford a far better conception of the physical geology of North-Western India. By far the most important, and, so far as is known, the most complete, series of tertiary formations yet examined is found in Sind, where, above the upper flow of Deccan trap, sandstones, above 2,000 feet thick, probably of freshwater origin, are found, passing up into the marine Ranikot beds, with a lower eocene fauna. To these succeed the nummulitic limestone or Khirthar group, 500 to 3,000 feet thick; a distinctly marine formation in general, but passing locally into a mass of sandstones and shales having a littoral aspect. The uppermost bands of limestone contain a different fauna; the *Foraminifera* especially being distinct from those of the Khirthar group, and including but two species of *Nummulites*, one, *N. garansensis*, found only in upper eocene and lower miocene beds in Europe, and a second, *N. sublævigata*, peculiar to India. With these upper limestones, sandstones and shales are intercalated; the marine beds soon die out, and a great thickness of sandstones without marine fossils, and probably of freshwater origin, succeeds. The whole of these beds, from the limestones with *Nummulites garansensis* upwards, including 4,000 to 6,000 feet of strata, are classed as the Nari group, and believed to represent the upper eocene and lower miocene of Europe. The Gáj group, 1,000 to 1,500 feet thick, comes next, chiefly composed of marine beds, with an upper miocene fauna; the uppermost layers, however, containing estuarine shells, and passing into freshwater, probably fluviatile, clays

and sandstones, with mammalian bones. These last beds form the lower Manchhars, and are believed to represent the Lower Siwaliks, or Nâbans, of the Sub-Himalayan area. The whole Manchhar group comprises in places 10,000 feet of beds, chiefly sandstones and clays, capped by coarse conglomerates, and is considered equivalent to the uppermost miocene and pliocene of Europe. With the exception of occasional estuarine beds near the base, the Manchhar group appears entirely of freshwater origin.

The miocene Gáj beds are not traced north of Sind; in the Punjab the only marine tertiary formations known are of eocene age.

The eocene beds in the Salt Range of the Punjab appear closely to resemble those of Sind, except that the Nari group has not been detected in the former locality: in both cases sandstones and alum clays with lignite underlie the nummulitic limestone. The lowest eocene marine beds in the Salt Range, however, are beneath the lignite and alum group; whereas in Sind the Raniket marine beds overlie a precisely similar formation; and consequently some eocene fossiliferous bands of the former locality may be older than any Sind tertiary beds—a distinction apparently confirmed by the fauna. Above the nummulitic group in the Salt Range there is a break in the sequence, neither Nari nor Gáj beds being known; and it is even doubtful whether the lowest members of the Manchhar or Siwalik group are represented. To the westward, in Kohát, the limestone is thinner, and marls, clays, and sandstones are intercalated; the underlying lignite and alum clay group appears to be wanting, or replaced by red clays, resting upon gypsum and a bed of rock-salt, 300 to 700 feet thick, and probably even thicker in places. Above the nummulitic limestones are upper tertiary sandstones and clays of freshwater origin, as in the Salt Range. In the Eastern Punjab, along the base of the Himalayas, the tertiary rocks consist of two series, unconformable to each other in the Simla area, but undistinguishable by any break farther to the north-west: the lower or Sirmúr beds, comprising three groups, known in ascending order as Subáthu, Dagshai, and Kasauli; and the upper or Siwalik series, composed of lower Siwalik or Náhan beds, middle and upper Siwaliks. Marine beds are confined to the lowest or Subáthu group, which corresponds to the Khirthar group of Sind. Lastly, in the extreme north of the Punjab, the nummulitic limestone of Hazára, Chita Pahár, the Afridi hills, &c., is interstratified with shales, and much contorted and hardened. It is separated from the newer tertiary beds by a line of fault or disturbance. Some bands containing nummulites are found at the base of the overlying rocks, and are evidently of eocene, though perhaps of upper eocene, age; but the whole series above them, consisting of the Murree beds and the Punjab representatives of the

Siwaliks, although attaining an enormous thickness, and occupying a very large extent of country, is destitute of marine bands, and even of well-marked sub-divisions.

The massive nummulitic limestone is probably an open-sea deposit; but, despite its thickness, it varies so much in composition, and passes so often into sandy and shaly beds, as to indicate in many places the vicinity of land. It is well developed throughout the greater portion of Sind, and is found represented in the middle of the Indus valley, near Sakkar (Sakhar) and Rohri, and to the eastward, between Rohri and Jesalmir (Jeysulmere). It extends throughout a great portion of the Sulemán range, and appears, as just shewn, in the Salt Range of the Punjab, and again in the Northern Punjab. To the westward, it is known to stretch through Baluchistan and Persia to the Caucasus and Asia Minor, and thence into Southern Europe. Eastward from the Salt Range, although marine nummulitic beds are found over a considerable area, the interstratification of sandstones and shales, often with terrestrial plants in places, shews the deposits to have been more or less littoral. With the data already given, an attempt may now be made at tracing the Indian coasts of the nummulitic sea.

So far as the eocene beds of Southern Baluchistan are known, they consist of sandstones and shales, and indicate the neighbourhood of land at the period of deposition. This is the case north of Gwádar, and again near Karáchi. The nummulitic limestone thins out greatly, and becomes intercalated with shales and sandstones, in Southern Sind, in Cutch, and in Guzerat. This occurrence of littoral beds along the present coast line may shew that land existed either to the southward, in the area now occupied by the Arabian Sea, or to the north-west. The absence of any eocene marine beds on the coast of the Indian Peninsula, from north of Bombay to the mouth of the Ganges, renders it probable that a considerable expanse of land existed at this epoch; and the land area may very possibly have extended towards Africa, as in cretaceous times, and probably in the miocene period. From the neighbourhood of Surat the nummulitic shore probably extended to the east of Kattywar and Cutch, then possibly, and at a later period certainly, islands, and thence ran through the western portion of the great desert to the Punjab. The sea extended to the north-east as far as Gahrwál, where the most eastern patch of Subáthu beds occurs; but there is no evidence of marine conditions in the Ganges valley between Kumaun and the Gáro hills, south of Assam. The Subáthu nummulitic beds are clearly littoral deposits, and by their aid we may trace the shore line along the south of the Himalayas to the Pir Panjál. The nummulitic limestones of Hazára and

the hills of the Northern Punjab near Attock and Pesháwar are all interstratified with shales; but the formation is of great thickness, and may have been formed in the open sea. That the sea extended northward, is shewn by the existence of nummulitic beds, much altered, in the Upper Indus valley; but they appear to be restricted to the neighbourhood of the river, and it is probable that they were deposited in an arm of the sea, while the surrounding area of Western Tibet was dry land.

It is impossible to say how far eocene rocks can be traced to the north of the Himalayas, in Tibet and Central Asia: some supposed nummulitic beds north of Sikkim have not been sufficiently identified for certainty. Marine eocene beds are found to the south of the Himalayan axis in the Assam range, and thence to the southward, throughout a considerable area, in Burma, west of the Irawadi. Many of the rocks are somewhat altered, and fossils, although found in many places, are often wanting throughout large areas. The marine nummulitic formation has not been observed in Tenasserim; but it is probably continued in the Andamans and Nicobars, and it reappears in Sumatra, Java, and other islands of the Malay Archipelago. Throughout this eastern region freshwater beds with coal are of common occurrence in the eocene rocks; and even in the marine beds coarse sandy deposits frequently indicate deposition near a shore. It is highly probable that the metamorphic area of Eastern Burma was land in the tertiary period, and that the older tertiary deposits of Assam, Burma, and the Malay islands were formed in a deep gulf, or around and amongst an archipelago, like that now existing farther to the south-east. It will hereafter be shewn that some peculiarities of the recent fauna indicate a connexion between the Malay islands, Southern India, and Africa in early tertiary times; and a land area may have extended to the south of India at this period.

Distribution of eocene land.—It will thus be seen that the Peninsula of India in eocene times was part of a tract of land, perhaps of a great continent united to Africa; that there was a sea to the eastward, extending far to the north-east, in the region now occupied by the Assam hills, and another sea to the north-west, covering great part, if not the whole, of Persia, Baluchistan, the Indus plain, and a portion of the Upper Ganges plain. An arm of this sea extended from the north-west up the Upper Indus valley in Ladák. The Himalayas, and perhaps Tibet, wholly or in part, were raised above the sea; but formed in all probability land of moderate elevation. Whether the Himalayan land was united to the Peninsula is, of course, uncertain—but very probably it was; for there is no evidence of marine conditions having existed in the Ganges plain to the east of the Dehra Dún; and if the ferruginous bands of the

Subáthu group be laterite, as they appear to be, the trappean detritus composing them must have been derived, in all probability, from the peninsular area; and the latter must consequently have extended northward, to the base of the Himalayas, in the neighbourhood of Umballa.

It is probable that in the later eocene period of the Nari and Dagshai beds, the sea still flowed as far north as the Punjab; for some Nari *Foraminifera* has been found in that direction: but it is evident that the marine area was diminishing; for the mass of the Nari beds, even in Sind, appear to be of freshwater origin. In miocene times, although marine conditions prevailed throughout Western Sind, the area of the sea was very much smaller than in the eocene period; for all the marine beds of the Punjab and Sub-Himalayas are destitute of marine fossils, and are probably fluviatile deposits.

Later tertiary beds.—East of the Indian Peninsula the area of middle tertiary rocks can be but ill defined for want of information. Marine beds of this age are found in Pegu occupying an extensive area; and if, as appears probable, some marine deposits in the Gáro hills, resting unconformably on the nummulitic limestone, are of miocene age, the difference in extent between the lower and middle tertiary seas in the Bay of Bengal area was probably less than to the westward. All pliocene beds in Assam and Burma appear to be of freshwater origin, with the possible exception of some in the Gáro hills; indeed, after miocene times, the land areas of South-Eastern Asia must have assumed to a great extent their present contour. It has already been pointed out that, for the first time in geological history, the delimitation of the Malabar coast line is indicated in the miocene period.

Some marine beds of late tertiary age, largely developed along the coast of Baluchistan, and hence called the Makrán group, are very probably marine equivalents of the Manchhars and Siwaliks. This would be in favour of the Baluchistan coast line having also assumed its present approximate outline in later tertiary times. The indications of a connexion of land between India and Africa in the tertiary period, as illustrated by the recent fauna, will be discussed in the sequel.

Siwalik fauna.—The mammalian fauna of the later tertiary deposits has received more attention than the fossils of most Indian formations. A most important and interesting assemblage of mammalian remains has been preserved in the middle and upper Siwaliks, the two highest groups of the Sub-Himalayan series. In these beds 84 species of mammals have hitherto been detected, belonging to 45 genera, the whole assemblage having more resemblance to the miocene of Europe than to any later European fauna, but containing a larger proportion of recent genera, and

especially of ruminants, than is found in the miocene elsewhere. Of the associated reptiles, several are recent species; and all the freshwater and land shells found appear to be identical with living forms.

The Náhan beds, forming the lowest group of the Siwalik series, have hitherto proved unfossiliferous; but in the Lower Manchhar beds of Sind, teeth and other remains of a considerable number of species have been found, chiefly of *Ungulata*, comprising, together with several Siwalik species, some genera not known in the Siwalik fauna, and having an older facies. The number of recent genera and of ruminants, in the Manchhar fauna, is very small, whilst several typically miocene genera occur, unknown in the beds of the Siwalik hills. There appears good reason to believe that the Siwaliks and the Manchhars are approximately equivalent, and that the Lower Manchhars probably correspond to the Náhan group. As, however, the Manchhars rest upon the Gáj beds, which are probably upper miocene, it is evident that the Siwalik fauna cannot be older than pliocene. The Siwalik mammalia resemble those of Pikermi in Attica more than any other known fossil fauna; and the Pikermi beds, although they contain a large number of miocene species, and are frequently classed by various writers as miocene, are shewn to be really of pliocene age by containing, at their base, pliocene marine fossils.

Remains of mammalia of Siwalik species have also been found at Perim Island in the Gulf of Cambay, off the coast of Guzerat, and in the later tertiary beds of Burma, which, like the Manchhar beds, overlie miocene marine strata. In both cases the fauna, so far as known, is comparatively poor; but in each instance there is about the same proportion of Siwalik species. There is nothing to indicate that the fauna of the Irawadi beds is older than that of the Siwaliks; and the Perim Island mammalia, although comprising *Dinotherium*, and wanting some of the recent genera found in the Siwalik beds, appear to be of nearly the same age as the latter. It must be inferred, therefore, that in pliocene times there was land communication between the Sub-Himalayan area, Guzerat, and the Irawadi valley.

The valley gravels of the Indian Peninsula, and especially some fossiliferous beds in the Narbada valley, contain a few Siwalik mammalia, associated with species more nearly allied to those now living. Remains of human implements have also been detected in these gravels, which are probably of post-tertiary or pleistocene age.

The marked resemblance between the Siwalik fauna and that of the European miocene may be due to a migration to the southward of the fauna inhabiting Northern Asia and Europe towards the close of the miocene period, when, as is known from other data, the temperature of the northern hemisphere was becoming colder. There is a marked affinity

between the Siwalik fauna and that now found in the Indian Peninsula, an affinity much greater than there is between the Siwalik and Malay fauna; and several genera of Siwalik mammals no longer living in India are found still existing in South Africa. This may be due to the admixture of the fauna inhabiting India in pre-Siwalik times with the Siwalik immigrants; for, as will be shewn, there is a probability that the Ethiopian elements of the Indian and Malay faunas are descendants of earlier immigrants than the pliocene Siwalik types; or (and this is perhaps the more probable view) the existing mammals both in India and in Africa are descended in part from the miocene inhabitants of Europe and Northern Asia, driven southward at the commencement of the cold cycle, which culminated in the glacial epoch, and some genera which have died out in India have survived in Africa. The occurrence of so many species of the Central European miocene beds in the pliocene rocks of Greece is very possibly due to the same migration to the southward.

Origin of Himalayas.—During the interval that has elapsed since eocene times, whilst no important movements, except small and partial changes of elevation, can be traced in the Peninsula, the whole of the gigantic forces, to which the contortion and folding of the Himalayas and the other extra-peninsular mountains are due, must have been exercised. The Sub-Himalayan eocene beds were deposited upon uncontorted palæozoic rocks; and although the Himalayan area was probably in great part land at a much earlier period, there is no reason for believing that this land was of unusual elevation, whilst the direction of the Himalayan ranges is clearly due to post-eocene disturbance. It will be shewn, in the chapters relating to the Sub-Himalayan rocks, that the movement has been distributed over the tertiary and post-tertiary period; and a great portion is of post-pliocene date. Indeed, the fact that earthquakes are now of common occurrence in the Himalayas, the Assam hills, Burma, Cutch, and Sind, and that many of the shocks are severe and some violent, whilst the peninsular area is but rarely affected by earthquakes, may indicate that the forces, to which the elevation and contortion of the Himalayas are due, are still in action; and that the highest mountains in this world owe their height to the fact that the process of elevation is still in progress, to a sufficient extent to counterbalance the effects of denudation.

If, as appears probable, the intercalation of a laterite bed in the Subáthu eocenes shews that the latter strata were of contemporaneous origin with the high-level laterite of the Deccan, which is always posterior in date to the Deccan traps, it is evident that the main Himalayan disturbance is of later date than the Deccan trap period; although the pre-tertiary Himalayan elevation, unaccompanied by folding, may be

older than the traps, or of the same age. In several localities along the base of the Himalayas, basaltic traps are intrusive in the old palæozoic rocks of the mountains. These traps are, however, suspected to be of later tertiary age, and newer than the Deccan traps; for they are said in one locality to penetrate the Sub-Himalayan beds, and in another locality, where Sirmúr beds are entirely composed of detritus from the neighbouring palæozoic strata, no fragments of the trap, now so extensively intruded into those strata, are found. These Himalayan intrusive rocks may be of the same date as the contortion and folding of the beds.

In Sind and the Sulemán ranges, there is much probability that some movement took place during miocene and pliocene times. Some slight unconformity between beds, elsewhere conformable, and the absence of different groups in parts of the country, may thus be explained; but the principal disturbance is clearly of post-pliocene date. To the eastward, in Burma, however, the pliocene formations of the Irawadi valley are but little disturbed, and the miocene beds, although contorted, are unaltered; whilst many of the eocene and cretaceous rocks are greatly changed, besides having undergone excessive disturbance and folding. These facts may, perhaps, indicate that the disturbing forces were more severe to the eastward in middle tertiary times, and that the main action to the westward was of later date: a view partly supported by the fact that there is evidence of elevation having taken place in the Himalayas near the Ganges and Sutlej, at an earlier period than farther to the westward. In the Simla area, there is marked unconformity, due evidently to upheaval and denudation combined, between the Sirmúr and Siwalik series, and between the lower, or Náhan, group of the Siwalik series itself and the next overlying sub-division; whereas farther west, in the Northern Punjab, all the groups follow each other in apparently conformable sequence. The evidence, however, is not sufficient to prove that the contortion to the eastward is older than to the westward; and the absence of any important break in Burma is opposed to the suggestion of great movements having taken place in that country in early or middle tertiary times.

It is evident that the forces, to which the principal ranges in the extra-peninsular area owe their direction, have not only been exerted throughout a considerable portion of the tertiary period, but that these forces have acted contemporaneously, at all events in the post-pliocene period. Yet the directions of the ranges vary in the most remarkable manner, as has already been pointed out on a previous page, and shewn on the sketch map in the commencement of the present Introduction. It would be difficult to conceive clearer evidence: taking only the north-

western area, amongst the mountain ridges that encircle the Indus plain, and comprise pliocene beds, are found ranges running north and south, as the Khirthar and Sulemán; east and west, as the Mari and Bhugti and the Afridi hills; north-west and south-east, as the Pir Panjál; north-east and south-west, as the Eastern Salt Range and Kharian hills; and many intermediate directions may also be traced, independently of curved ridges. Similar differences of direction are to be found to the eastward of India. It is manifest, in the face of so much variation in strike amongst ridges of contemporaneous origin, that arguments in favour of the connexion between distant but parallel ranges should be received very cautiously; and the establishment of cotemporaneous "systems" must depend upon more valid data than the direction of mountain chains.

What the forces can have been that produced the great disturbance and folding of the rocks manifested in the various mountain chains is so difficult a subject, that nothing would be gained by discussing at length the various guesses—for they are little more—hitherto put forward. The only point on which most modern geologists appear to be agreed is, that lateral pressure has been exercised; and by many writers the lateral pressure is attributed to shrinking of the earth's crust, through the cooling of the interior. It is evident, if this be admitted, that the pressure has come, in the case of the extra-peninsular ranges of India, simultaneously from various directions. Even the side from which the force has been exerted in each case is very far from easily determined, owing to the circumstance that the contortion of rocks is due to two opposite and equal pressures—a moving force and a resisting mass—and it is not always easy to distinguish the effect of the one from that of the other. It has been argued by Suess,[1] mainly from the resemblance between the phenomena exhibited by the Sub-Himalayan series, and especially by the Siwaliks, to the south of the Himalayas, and the features shewn by the *mollasse* to the north of the Alps, that the lateral movement, to which the contortion of the Himalayas is due, came from the north, in the same manner as the thrust in the Alps was from the south. This view of Suess, it may be stated, is in accordance with the observations of the Indian Survey, and founded upon them; and if, as appears most probable, lateral movement be accepted as the cause of mountain-formation, the southward thrust of the Himalayan mass may be a correct explanation of the phenomena. The Northern Punjab, west of the Jhelum, as Suess points

[1] Entstehung der Alpen, pp. 126—144. In this valuable work a good summary of the views of previous writers will be found, and abundant references to the literature of the subject. Some remarks bearing on the same matter will be found in Prof. Martin Duncan's Presidential Address to the Geological Society of London in 1877: Proc. Geol. Soc., 1876-77, pp. 67—69, &c.

out, has evidently been affected by a force moving from a different central area, and not by that to which the strike of the Pir Panjál and the Himalayas generally is due. One indication of this difference, and an indication which may shew that the commencement of movement was not contemporaneous in the two areas, is that, east of the Jhelum, in the Pir Panjál, there is a great break at the base of the eocene; whereas west of the Jhelum a similar break, there attributed to a great fault, intervenes between lower and upper eocene beds.

But the curves of the Salt Range, and especially the deep re-entering angle at the Indus, are so much sharper than those of the ranges to the northward, that, despite the smaller degree of disturbance in the Salt Range, there must have been in this area a thrust, or series of thrusts, from the south. This latter force may, of course, have taken the form of resistance to the northern movement; but it exemplifies the difficulty, already referred to, as to the direction of the thrust. Again assuming, as in the absence of all indication of disturbance in tertiary times in the peninsular area we must assume, that this central area remained fixed, and the crust disturbances came from without, we must suppose a lateral movement from the westward on the Western Sind frontier, from the northward in the Mari and Bhugti hills, north of Jacobabad, from the west or west by north again in the Sulemán, from the north in the Safed Koh and Afridi hills, from the north-west in the Hindu Kush and most of the Afghanistan ranges, from the north along the upper Punjab, between Pesháwar and Abottabad, and from the north-east in the Pir Panjál; from the northward throughout the greater portion of the Himalayas, from north-west (or south-east?) again in the extreme Eastern Himalayas, and from the south-east in the parallel Nága hills; whilst in Burma, as a rule, the thrust has come from the eastward. To the west of India, beyond the Sind frontier, for about 300 miles, the ranges strike east and west, shewing a thrust from north or south; thence throughout the greater part of Persia the direction of the mountain chains is north-west and south-east. The ranges of Baluchistan and Persia,[1] it should be added, are largely composed of tertiary rocks, and may probably be of contemporaneous origin with the Himalayas. Taking the Persian area and that of the Himalaya and Tibet, it will be seen that the mountain ranges fall roughly into two great curves convex to the southward; but the deeper western curve has produced the smaller mountain ranges. That a gigantic lateral movement has taken place in the apex of this western curve is, however, shewn by the fact that for nearly 150 miles between Gwádar and Jálk in

[1] Eastern Persia, I, pp. 1—17, and maps.

Baluchistan the track traverses beds, all apparently of tertiary age, at right angles to their strike, and that all these beds are vertical, or nearly so. The contraction in breadth, or, in other words, the lateral movement, must have been great to have converted horizontal formations into a series of undulations, with dips so high as those seen in the Baluchistan ranges.

Origin of Indo-Gangetic plain.—It would be unprofitable to enter into further discussion on this difficult question : the hypotheses of mountain formation require much to be added before they can be incorporated in the body of geological science, and considered as data on which to found inferences as to the history of the world. But before quitting the subject of the extra-peninsular hill ranges, a few words as to the origin of the remarkable Indo-Gangetic plain, from the outer margin of which they rise, may not be out of place. The popular conception of this plain, an idea repeated in numerous geological and zoological treatises, is that the area is an ancient sea, filled up by deposits brought in by rivers. This view is natural enough : the vastness of the plain, across which, even at its narrowest part, the highest mountains of the world are barely visible, must strike even the most ordinary spectator with its resemblance to a sea-bed. The great contrast between the Himalayan and peninsular formations, and the much greater prevalence of marine beds on the small accessible area of the northern region, also lend weight to the idea of a sea having separated the two.

It should, perhaps, be admitted at once, that, as in the majority of geological speculations, the evidence is imperfect, and the greater portion is negative. There is absolutely no proof of any sort or kind, that the whole Indo-Gangetic plain has at any time been a marine area; but there is equally no proof that it has not. It has been shewn that, in eocene times, the sea occupied the Indus valley as far as the foot of the Himalayas, and extended along what is now the base of the mountains, as far east as Kumaun; and also that marine conditions prevailed to the north-west throughout a great part of the tract now occupied by the Assam range; but it was also pointed out that, in the area between Kumaun and the Gáro hills, no trace of marine formations had been found. Yet it is difficult to understand, if the Gangetic plain was a sea-basin, why no marine beds occur. It is true that the northern border of the plain, throughout the most important part of the intervening space in Nepál, is unfortunately inaccessible to Europeans; but still, if the Gangetic plain in any way corresponds to an eocene sea, as the Indus plain doubtless does, why are no traces of marine beds found to the south of the valley, on the margin of the peninsular area, as they are in the desert to the east of the Indus? In the Brahmaputra plain, also, no

marine deposits of tertiary age are found; in the plain itself only fluviatile deposits have been detected, and the marine eocene and miocene beds are confined to the southern slopes of the range, forming the southern watershed of the valley.

It was shewn that the jurassic traps of the Rájmahál hills, west of the Ganges delta, were very possibly once continuous with those of Sylhet, east of the deltaic area; that the coast line, in cretaceous times, ran from the present eastern coast line of the Peninsula to the Assam Range; and that there is no indication of any cretaceous bay running up the Ganges valley; but, on the contrary, the absence of any marine deposits between Rájámahendri and the Gáro hills rather indicates that the old coast line ran across what is now the Bay of Bengal. It is far from improbable that the nummulitic coast line approximately coincided with that of cretaceous times, as the cretaceous shore nearly followed the old line traced in the upper jurassic period. Miocene marine deposits are to the eastward similarly restricted to eocene, and more so in Western India. As already noticed, it appears certain that those tracts in the Punjab, which had been marine in eocene days, were land in the miocene epoch and in later tertiary times: the immense thickness of upper tertiary beds of freshwater origin, now upraised along the western and northern border of the Indo-Gangetic plain, from the mouths of the Indus to the eastern end of the Assam valley, negative the idea of marine conditions. The occurrence of the same mammals in the pliocene beds of the Sub-Himalayas and of Perim Island has already been noticed as evidence of land communication between the two areas. Amongst still later beds, the post-tertiary formations of the North-West Provinces are clearly river deposits; and in Calcutta itself, within the tidal creeks of the delta, a boring to a depth of 480 feet, 460 being beneath the present sea-level, traversed beds in which the only fossils observed were terrestrial or fluviatile. These beds, moreover, comprised gravel too coarse to have been deposited in an open sea; whilst at 385 feet from the surface a peat bed was found, clearly of terrestrial origin. All tends to shew the gradual depression of an area composed of fluviatile formations throughout all the later tertiary periods. The sea may, at times, have extended some distance from the present coast; for it is improbable that sinking and the deposition of sediment can have gone on so evenly, and that land only just above high water has always been kept at the same relative level, despite ages of depression; but there is nothing in the data known to indicate marine deposits.

In the neighbourhood of the Indus delta the sea probably extended some distance inland at a late period; and both Cutch and Kattywar may

have been islands at a very recent geological epoch. It is clear, however, that the two species of Siwalik elephants, and the buffalo found in the Narbada gravels, could not have traversed the Indo-Gangetic plain, had it been occupied by the sea in pliocene or post-pliocene times. It will be seen that the number and variety of data opposed to the idea of a sea having intervened in the place of the Indo-Gangetic plain between the Peninsula of India and the remainder of Asia during or since the tertiary epoch are considerable, and all the facts are adverse. It must also be manifest that there is no evidence that any such depression as the Indo-Gangetic plain existed in pre-tertiary days; for if it had, we should probably find marine jurassic or cretaceous rocks along the foot of the Himalayas, if not on the margin of the peninsular rock area also.

Thus we are brought in face of a very important conclusion; and it becomes highly probable that the Indo-Gangetic depression is of contemporaneous origin with the disturbance and contortion of the Himalayas and the other extra-peninsular ranges, and that the physical features of the two areas are closely connected. The coincidence in general outline, the parallelism in fact between the great area of depression and the ranges north, east, and west of it, tend to confirm this view. The plain of the Ganges and Brahmaputra continues along the foot of the Himalayas throughout; the Indus plain turning southward where the ranges in the Western Punjab and Sind run north and south, and the estuaries of the Ganges and Brahmaputra being similarly deflected in front of the north and south hills of Tipperah and Chittagong. It is not unreasonable to believe that the crust movements, to which the elevation of the Himalayas, and of the Punjab, Sind, and Burmese ranges are due, have also produced the depression of the Indo-Gangetic plain, and that the two movements have gone on *pari passu*. That the depression of the deltaic area of the Ganges is still in progress, is shewn by a series of facts, of which the evidence afforded by the Calcutta bore-hole is one; and it has already been suggested that the disturbing forces affecting the Himalayas are still in action.

Now, there is a theory, originally attributed to Prévost, but largely adopted and modified by later geological writers, that the elevation of mountains is due to the depression of a neighbouring area. It is clear that if an arc of a circle tends to become flatter, and to approximate to a straight line, the horizontal extent must be increased, because every arc of a circle is longer than its chord. If one portion of a rigid circle be slightly depressed, a neighbouring portion, being compressed into less horizontal space, and having in fact the length of its chord diminished, must bulge out. Applying this fact to the earth's surface, it is clear

that the depression of any portion would produce lateral thrust, and this might cause the bulging of a neighbouring area. Of course, there is a limit: after a certain amount of depression, the arc and chord would coincide in direction, and farther depression would cause the surface to take up less space horizontally, instead of more. The depressions have been called geosynclinals, and the elevations geanticlinals by Dana.

At first sight it would appear as if the theory, as applied to mountain formation, depended partly on the assumption of the earth's internal fluidity; but a little reflection will shew that such is not the case; greater radial contraction of one segment of a sphere, or of one portion of any great circle intersecting the sphere, would depress the surface; and if the superficial portion did not contract equally, would cause lateral pressure. It is assumed, it should perhaps be stated, when changes on the earth's surface are attributed to the shrinkage of the interior through cooling, that the crust, having already cooled, would not contract in proportion.

A very simple calculation, however, shews that the depression, even of so large an area as the Ganges plain, could not have produced the elevation of the Himalayas. The Himalayan belt, between the plains of India to the south and the line of the Indus and Brahmaputra or Sangpo to the north, has an average breadth scarcely, if at all, inferior to that of the Gangetic plain, even if the plateau of Northern Tibet be omitted from the calculation, and supposed to owe its elevation to movements in Central Asia. Assuming that both the Himalayan and Gangetic areas originally differed but little in elevation, it is clear that the Himalayan portion of the arc of a great circle has been raised to the maximum height of the peaks, or 29,000 feet, in addition to all that has been removed by denudation. If the two arcs, that across the Himalayas and that across the Gangetic plain, be approximately equal, in order to produce a lateral thrust sufficient to raise the former, the surface of the latter must be capable of sinking through about an equal distance. The amount is not exactly the same; but in arcs of so small angular dimensions the difference would be trifling. Now, the arc subtended by the Gangetic plain is about 3°, and the height of such an arc of the earth's surface above the chord, or the distance through which the surface could sink and still produce lateral pressure, is only 7,000 feet; whilst the difference in length between the arc of 3° on the earth's surface and the chord of that arc is only about 126 feet. That is to say, the depression of the Gangetic plain could only have produced a lateral movement of 126 feet, and have raised the Himalayas to an elevation of 7,000 feet, provided all the lateral movement was expended in producing elevation.

It is thus evident, independently of the circumstance that the lateral movement appears to have come from the north, that neither the elevation nor folding of the Himalayas is due to the depression of the Gangetic plain alone. The formation of the Indo-Gangetic depression and of the Himalayas and other mountain chains is probably due to the same forces, without the one being in any way the cause or effect of the other.

Distribution of recent fauna.—There is still one question to be noticed before quitting the subject of Indian geological history: this is the light thrown by the distribution of living animals in different parts of the world on former connexions between India and other regions. The geographical distribution of animals has been very fully treated by Wallace,[1] who, following Sclater and some other naturalists, divides the surface of the globe into six great regions: (1) the Palæarctic, including Europe, Africa north of the Sahara, and Asia north of the Himalaya; (2) the Ethiopian, comprising the remainder of Africa, with Southern Arabia and Madagascar; (3) the Oriental, consisting of India, Southern China, Burma, Siam, &c., the Malay Peninsula, the Philippines, Sumatra, Java, Borneo, and the other Malay islands, to "Wallace's line" between Bali and Lombok; (4) the Australian, comprising the south-eastern islands of the Malay Archipelago, Celebes, New Guinea, Flores, Timor, &c., Australia, New Zealand, and all the islands of the Pacific as far east as the Sandwich, Marquesas, and Low Archipelagoes; (5) Nearctic; and (6) Neotropical, approximately corresponding to North and South America.

The classification adopted is open to some objections: the regions named are by no means equivalent to each other, and it is a question whether several do not require further sub-division. The differences between the Indian and Australian faunas, although the two regions are only separated in places by a few miles of sea, are very much greater than the distinctions between the animals inhabiting the comparatively distant Oriental and Ethiopian regions. Several other classifications have been proposed by Murray,[2] Blyth,[3] Von Pelzeln,[4] and others; all of whom agree in classing either the whole Oriental region, or a portion of it, in the same great sub-division with Equatorial and Southern Africa, or else in distinguishing Peninsular India as a region apart. There can be no question about the existence of a marked distinction between the

[1] Geographical Distribution of Animals, 2 vols., 1876.

[2] Geographical Distribution of Mammalia, 1 vol., 1866.

[3] "Nature," 1871, March 30, p. 427; Journ. As. Soc., Bengal, 1875, pt. 2, extra number; Introduction, p. xiv.

[4] Afrika—Indien: Verh. k.-k. Zool. Bot. Gesellsch., Wien., 1875, pp. 62, &c.

fauna of the greater part of the Indian Peninsula and that of the countries east of the Bay of Bengal; but as the question is an open one, it is convenient to adopt Wallace's nomenclature and limits for the present, so far as the great regions are concerned. It must, therefore, be understood that the territories and dependencies of British India, with the exception of the Himalayas, above about 7,000 to 10,000 feet elevation, are classed as belonging to the Oriental region; the higher portions of the mountains, together with the trans-Himalayan countries, belonging to a province of the Palæarctic region. In North-Western India, however, there is so large an admixture of Palæarctic forms, that no definite line can be drawn between the two faunas; Kashmir, for instance, and the North-Western Punjab near Peshâwar, having almost an equal proportion of types belonging to the two.

It is, however, impossible to assent without modification to the sub-divisions or sub-regions of the Oriental region proposed by Wallace. They are four in number: (1) the Hindustan or Indian sub-region; (2) the Ceylonese and South Indian; (3) the Himalayan or Indo-Chinese; and (4) the Indo-Malayan. The Himalayan includes Siam, Southern China, and all Burma, except the extreme southern portion of Tenasserim: the latter, with the Malay Peninsula, belongs to the Indo-Malayan sub-region. This division between the two sub-regions, so far as British territories are concerned, is correct; and the minute details of the great Indo-Chinese sub-region are not of so much geological interest as the distribution of the fauna in the Indian Peninsula and its outskirts. From Wallace's Indian sub-region the Indus plain and the desert to the eastward must be separated and classed with the Baluchistan coast-land as a distinct sub-region, having a characteristic dry climate fauna and flora, with a large intermixture of Palæarctic forms; whilst the limits of the Ceylon and Southern Indian province require alteration. This sub-region, a very important one, with a peculiar fauna, having some marked affinities to that of the Malayan countries, comprises the whole Western or Malabar coast of the Peninsula, from north of Bombay to Cape Comorin; but not the central highlands nor the Coromandel coast, although several isolated hill-groups, such as the Shivarais, south-west of Madras, possess, on their higher elevations, a Malabar fauna and flora. This sub-region is better distinguished by the name of Malabar; it comprises the hills of Southern Ceylon, but not the plains forming the northern portion of the island.

It is of course unnecessary to enter here at any length into the peculiarities of the fauna: the points to which attention is desirable is such evidence of former connexion with regions, now separated by impassable

barriers, as is afforded by the existence of allied animals. As might be anticipated, a few Palæarctic forms are common in those parts of the Oriental region nearest to the Palæarctic boundary, and the number of such forms diminishes to the southward.

The importance of these types is derived from the fact, that they require careful distinction from Ethiopian genera; for there is a similar admixture of Palæarctic forms in the Ethiopian region. In the same manner several distinctively Malayan and Himalayan forms, of birds especially, are common in the Indian Peninsula, independently of the peculiar forms with Malay affinities in the Malabar sub-region; and it is probable that Malayan forms are, in many cases, recent immigrants.

Mammals and reptiles, owing to their more limited powers of migration, afford better indications of a former continuity of land than birds; whilst freshwater fishes and other animals inhabiting rivers and lakes suffer from the serious disadvantage that, whilst the exact method by which they, or their ova, are transported, is not clearly understood, there is no doubt that they are capable of being carried alive from one piece of water to another by some natural agency. Hence the limits to their range are imperfectly known. The past history of land invertebrates is too imperfectly ascertained for the facts of their present distribution to be equally intelligible with that of vertebrates. On the whole, although the past history of mammalian vertebrates is still very imperfectly understood, it probably affords more data by which the probable migrations and origin of living species can be traced, and inferences drawn as to the original distribution of land, than does the existing knowledge of any other class of animals.

Ethiopian affinities of Oriental mammals.—Comparing, then, the mammalian fauna of the Oriental region, as a whole, with that of the three neighbouring regions, it will be found at once, that the strongest affinities are with the most distant of the three—the Ethiopian. Out of 35 families of terrestrial *Mammalia* ascribed to the Oriental region by Wallace, four are peculiar, or nearly so, viz., *Tarsiidæ*, *Galeopithecidæ*, *Tupaiadæ*, and *Ælurida*; one, *Tapiridæ*, is found also in the Neotropical region only, and six only (excluding stragglers in Celebes, and one or two of the other islands having an intermediate fauna) are found in the Australian region; four of these being bats, and a fifth, *Suidæ*, only extending beyond the confines of the Oriental region as far as New Guinea; so that the only terrestrial wingless mammalian family common throughout is the almost cosmopolitan *Muridæ*. The number of Oriental families found in the Palæarctic region is 21, whilst no less than 28 are common to the Oriental and Ethiopian faunas. Omitting such cosmopolitan families

as *Vespertilionidæ*, *Soricidæ*, *Muridæ*, *Felidæ*, &c., the numbers are 13 and 19. The families found in the Oriental and Palæarctic regions, but not in the African, are *Talpidæ*, almost confined in the former to temperate portions of the Himalayas and some other hill ranges, *Ursidæ* and *Cervidæ*. The families found in the Oriental and Ethiopian regions, but not in the Palæarctic, are *Simiidæ*, *Semnopithecidæ*, *Lemuridæ*, *Pteropidæ*, *Noctilionidæ*, *Manatidæ*, *Rhinocerotidæ*, *Tragulidæ*, *Elephantidæ*, and *Manididæ*. A species of *Semnopithecidæ* is found at a high elevation in Eastern Tibet, and another species ranges above most Oriental forms in the Himalayas; but in neither case can the animal be said to inhabit the Palæarctic region.

Of these families, the bats and dugongs may be neglected; the other families require a few words of notice. The *Simiidæ* are wanting in the Indian Peninsula, Ceylon, and the Himalayas. The *Semnopithecidæ* occur almost throughout the region; the *Lemuridæ* are represented by one genus confined to Southern India and Ceylon, and by a second genus in the countries east of the Bay of Bengal: none occur in the Himalayas, nor in the greater part of Peninsular India. The *Rhinocerotidæ* are unknown wild in the Indian and Malabar sub-regions; the *Tragulidæ* are represented by one genus or sub-genus in India and Ceylon, and by another in the countries east of the Bay of Bengal: this family, also, is not represented in the Himalayas. The *Elephantidæ* and *Manididæ* are more generally distributed. The *Rhinocerotidæ* and *Elephantidæ* had so extensive a distribution in the later tertiary period, that they furnish no inference of importance as to the former connexion of land areas; the ancestor of the existing Oriental species might have been derived from either the Palæarctic or Ethiopian region.

One remarkable fact may be gathered from these few details; and this is, that the peculiarly Ethiopian families are better represented to the south and east of the Oriental region than to the north-west. The orangs, the nearest allies of the African *Simiidæ*, are only found in Sumatra and Borneo; the lemurs are wanting throughout the northern portion of the region, and so is *Tragulus*. These forms, in fact, appear more or less isolated, as though they had formerly had a more extended range. The same thing occurs in Africa. The only Ethiopian representative of the *Tragulidæ* is confined to Western Africa; and so are the two genera of lemurs most nearly allied to the Oriental forms, and the African representative of the typically Oriental genus *Paradoxurus*. The *Simiidæ*, too, are confined to Western and Central Africa. Another curious instance of the isolation of types shewing affinity between the African and Malay faunas consists in the occurrence in Celebes, beyond the limit of the

true Oriental region, and associated with a mixed Oriental and Australian (Austro-Malay or Papuan) fauna, of a monkey, *Cynopithecus*, more nearly allied to the African baboons than to any of the Indian and Malay species. The same island possesses the peculiar bovine form *Anoa*, allied to a buffalo.

These cases of isolation probably indicate that the animals belong to an older fauna, now partly replaced by newer types, and that this older fauna was common to India and Africa. It is very probable that these animals are descended from the ancient tropical fauna of the early tertiary times. But, so far as it is possible to judge, the process of variation would have caused a greater distinction between forms so widely separated, and exposed to such different conditions, if the period of isolation were great; and it is difficult to suppose that the lands inhabited by the ancestors of the *Simiidæ*, *Lemuridæ*, *Tragulidæ*, and *Manididæ* of the Oriental and Ethiopian regions can have been separated prior to the early part of the miocene period.

It must be remembered that the whole evidence is far more extensive; the mammalia are merely selected as affording the best examples. It may reasonably be inferred that during part of the early tertiary period India was united to Africa, and the union may have been continuous from the cretaceous period to miocene times. The course of the old continent may perhaps be traced by the Maldive and Chagos archipelagos, and by the banks between the Mascarene islands and the Seychelles. That portions of the old land remained, broken up into islands, long after the connexion had been severed, is probable from some peculiarities amongst the birds of the Seychelles and Mascarene islands: thus the genus *Hypsipetes*, a characteristically Oriental form, is represented in Madagascar, Bourbon, Mauritius, and the Seychelles; and *Copsychus*, an equally typical Eastern genus, occurs also in Madagascar and the Seychelles. It is easily conceivable that birds should fly, or be blown, from island to island long after the distance was too great to be traversed by mammals. The circumstance that the mammalian fauna of the Oriental region shews less affinity with Madagascar than with that of the African continent, is perhaps due to Madagascar having been separated before the submergence of the land connecting Africa and India.

The southern portion of the Indian Peninsula with Ceylon may have been united to the Malay countries in tertiary times, perhaps later than with Africa. This, however, is not clear: despite some remarkable points of affinity to the Malay fauna, there are very remarkable differences; and when representative forms are found in Southern India or Ceylon and in the Malay countries, such forms are frequently, perhaps most fre-

quently, generically distinct. One of the most singular cases of generic alliance is the occurrence of a species of *Draco*, a Malay genus of lizard, in Malabar; but this is exceptional. Most of the genera of Ceylonese and Southern Indian lizards and snakes are peculiar; and one family of snakes is confined to the sub-region, and to some hill tops in Southern India. So far as the sea bottom between Ceylon and the Malay archipelago is known, there is nothing to indicate a former continuity of land in this direction; and the similarity of the fauna may perhaps have another explanation.

Ethiopian affinities of Indian mammals.—The affinities with the Ethiopian fauna hitherto mentioned are those of the Oriental region generally, and are, as already noticed, perhaps more marked in the southern part of that region than elsewhere; but, besides these, there are some very curious and prominent relations between the mammals and other animals of Africa and those inhabiting the Indian Peninsula alone, and not represented by any allied forms in the other Oriental sub-regions. As examples, the common antelope, *Antilope*, the nilgai, *Portax*, the four-horned antelope, *Tetracerus*, and the ratel, or Indian badger, *Mellivora*, may be quoted. In the case of *Mellivora*, the resemblance of the African and Indian forms is very great; but the antelopes are generically distinct. None of the animals mentioned is represented by allied species in Baluchistan or Arabia. These alliances to the African fauna may indicate that the Peninsula of India was united to Africa after the Malay countries had been severed; and if so, the evidence just quoted in favour of a later union between Southern India and Malayasia must receive some other explanation; but the Indian antelopes may very possibly be descendants of forms inhabiting the region in pliocene times; and the resemblance of these animals to Ethiopian types may be due to the immigration, as already suggested, of a closely allied fauna into both India and Africa at the close of the miocene epoch.

A third class of Ethiopian affinities in the fauna of Peninsular India is exemplified by the Indian gazelle and Jerboa rat (*Gerbillus*). In this case, however, closely allied species are found in the intervening countries and in the southern Palæarctic region; and the migration into India may have been posterior to the glacial epoch.

Affinities of land shells.—It should have been mentioned that the affinities of Oriental genera of land shells, and especially of the operculate forms (*Cyclophoridæ* and *Helicinidæ*), indicate an alliance with the Australian, rather than with the African fauna. Some genera certainly have extended to the Mascarene islands, Madagascar, and Africa; but they probably went from east to west, as the number decreases to the

westward. Land mollusca are very possibly of high antiquity; and the resemblance in this case may be due to the older mesozoic communication between India and Australia. The mode of migration of these animals is, however, imperfectly understood.

Survival of older types in the Indian area.—This is perhaps the most convenient place to call attention to the survival of forms in India to a later period than in Europe; several such instances of prolonged existence have been noticed, and they are not peculiar to any particular period of geological time. Amongst the cases hitherto recorded is the appearance of *Hyperodapedon*, a triassic reptile, in Indian beds of middle or upper jurassic age, and the occurrence of the triassic *Ceratodus*, and of some liassic genera of fish in the same beds. Then middle jurassic plants in Europe occur in upper jurassic beds in India; *Globosi* ammonites, not known above the trias in Europe, are found in middle cretaceous rocks in India; *Megalosaurus* and an amphicœlian crocodile, not found above lower cretaceous in the former area, are met with in upper cretaceous strata in the latter. The appearance of miocene European forms in the pliocene Siwaliks, and the existence at the present day of mammals, like elephants and rhinoceroses, on land, and of numerous marine molluscan genera in the seas of India, long after they have disappeared from the European area, are additional examples. The cases are not sufficiently numerous to indicate any law of migration from north to south, nor is the tendency to survival in India universal; for, on the other hand, *Voltzia heterophylla* and the other Karharbári plants probably occurred in India before they appeared in Europe; and several genera of *Gasteropoda* that abound in the Indian upper cretaceous beds are not found in Europe in older rocks than eocene. Still the instances of survival of older forms in India are sufficiently numerous to be worthy of mention: how far they are due to the tropical position, or to the great antiquity of the land area, it is difficult to say.

Glacial epoch.—Amongst the most potent disturbing causes that have affected the fauna of India in late geological times, the general refrigeration of the area in the glacial epoch has in all probability played a conspicuous part. The former extension of the Himalayan glaciers has been shewn to have been considerable; and the occurrence of Himalayan plants and animals on the higher ranges of Southern India may be due to the retreat of these species in the first place towards the equator, and subsequently, as the temperature increased, to the higher parts of the hills. As examples, the occurrence of a Himalayan rhododendron, of a wild goat allied to a Himalayan species, and of several Himalayan land shells on the Nilgiri and other Southern Indian hills

may be mentioned. The isolation of such forms of the ancient Indo-African fauna as the *Simiidæ*, *Lemuridæ*, and *Tragulidæ* may have been due to the irruption of the Siwalik fauna, in pliocene times; whilst the latter, in its turn, has been impoverished, and to a great extent exterminated, by the increasing cold of the glacial epoch. It is easy to understand how the remaining descendants of the old miocene fauna may have been driven to the tropics, and that thus their absence in the northern part of the Oriental region has been caused. It is not impossible that the distinction between the Malabar and Malay faunas has been intensified by their separation, due to the climate of Northern India having been too cold for them in the glacial epoch.

Sub-recent changes of level.—The evidence of recent changes in elevation on the shores of the Indian Peninsula, and also to the westward, along the Makrán coast, and to the east of the Bay of Bengal, on the shores of Arakan and of the islands in the Bay, indicates a rise of land. In places depression to a small extent has also taken place; but this is unusual, and apparently local; it is singular, however, that evidence of depression is found in one instance, in Bombay Island,[1] within a mile or two of land, which has apparently been raised. The Sahyádri scarp, at a little distance from the west coast, has much the appearance of an ancient sea-cliff, and may perhaps indicate a former coast line; but this is far from certain. The circumstance, that the low-level laterite in the neighbourhood of both coasts rests upon a sloping plane of rock, apparently formed by marine denudation, in all probability indicates elevation at no distant period; the laterite in question being certainly post-tertiary on the east coast, and probably on the western also. The elevation on the west coast may probably have been greater than on the eastern, as the laterite near the coast is raised to a higher level; and in the great rivers running westward, the Tapti and Narbada, large plains of post-tertiary deposits are found, one of which certainly has been accumulated in a rock-basin, whilst no such plains are found in the rivers running eastward.

Along the Makrán coast, to the west of India, there is a sub-marine cliff, at a distance of about 10 to 20 miles from the shore. This cliff extends from a little west of Cape Monze to the entrance of the Persian Gulf, and is about 2,000 feet high; the depth of the sea increasing more or less suddenly from 20 or 30 fathoms to 300 or 400. Without further

[1] The evidence of depression has been noticed since pp. 375-377 were printed off, and consists of the discovery of a large number of trees, imbedded in mud on the spot where they grew, with their roots at a depth of twelve feet below low-water mark, on the eastern or harbour side of Bombay Island. Rec. G. S. I., XI, p. 302. Similar evidence was recorded, some years ago, by Dr. Buist.

details, it is difficult to say whether this sub-marine cliff indicates depression: such would be the natural interpretation of the phenomenon, and it is, on the whole, most probable that a former coast line of sea-cliffs has been depressed; but there is, in several places along the coast, evidence of recent elevation, in the shape of raised shell beds, &c., and there is a possibility that the line of sub-marine cliffs may be a fault. On the Arabian coast of the Gulf of Omán, however, about Muscat and the Straits of Hormuz, there is abundant evidence of depression at no distant period. The depressed area in the ocean south-west of India, as indicated by the Laccadive, Maldive, and Chagos atols, has already been noticed as possibly indicating the area of the ancient land communication between India and Africa.

Previous summaries of Indian geology: Calder, 1833.—Before concluding this Introduction, a brief notice of former general descriptions of Indian geology may be useful. Such general accounts are not numerous, and a reference to them will not take much space.

The earliest attempt at a sketch of Indian geology was written by Mr. James Calder, and forms the first paper of the Eighteenth Volume of the Asiatic Researches, published in 1833. This volume is chiefly composed of geological papers, and to these Mr. Calder's forms, as it were, an introduction. In this account, which occupies only 23 pages, the general distribution of the overlying trap formation in Western and Central India, and the great prevalence of granitic and gneissic formations both in the Peninsula and throughout the Himalayas, are correctly indicated; but, as might be anticipated, the knowledge of the sedimentary formations of India was at that time very imperfect. The writer passes the different provinces in review, noting what had been ascertained as to the rocks occurring in each case.

Newbold, 1844-1850.—The next account refers to the southern part of the Peninsula alone; but it is the work of one of the best, if not actually the best, of the earlier Indian geologists; and it has the peculiar advantage over all other summaries published up to the present time, that the author possessed an extensive personal acquaintance with the country described. Captain Newbold's Summary of the Geology of Southern India is published in Volumes VIII, IX, and XII of the Journal of the Royal Asiatic Society, and treats of the area south of Bombay and Ganjam. The various formations are classed as the Hypogene series (the metamorphic rocks of the present work); diamond sandstone and limestone (including the transition and Vindhyan series and some Gondwána beds); the fossiliferous limestone of Pondicherry (cretaceous); fresh-

water limestones and cherts (intercalated with the Deccan traps); laterite, with which are associated, in one section, the Pondicherry silicified wood deposit (Cuddalore sandstone) and the marine sandstone beds of Ramnád and Cape Comorin; older alluvium, including regur and kankar; modern alluvium and sand dunes; plutonic rocks (granite, greenstone, &c.); and newer or overlying trap.

The most important error in this classification was the association of the rocks now classed in the Gondwána system with the ancient "diamond sandstone" of transition or Vindhyan age. This appears due to Captain Newbold's having no personal knowledge of the Gondwána beds, and to their having been confounded with the older rocks by previous observers. Most of the observations recorded in the Summary are admirable; and altogether the paper is so valuable, that the neglect with which it has been generally treated, and the much greater notice attracted by Dr. Carter's account, are not easy to understand. Captain Newbold's observations will be frequently noticed in the present work.

Carter, 1854.—Dr. Carter's "Summary of the Geology of India between the Ganges, the Indus, and Cape Comorin," first published in 1854 in the Journal of the Bombay Branch of the Royal Asiatic Society, Vol. V, pp. 179–335, and republished with additional notes in 1857 in the author's very useful reprint of "Geological Papers on Western India," is a compilation of great merit, and is much more generally known, in India at all events, than Captain Newbold's description of the geology of Southern India; but it cannot be said to equal the latter, either in accuracy or originality. Dr. Carter's Summary treats of a larger area than Captain Newbold's—of the whole of Peninsular India, in fact; but it suffers from the serious disadvantage that the author was personally acquainted with but an extremely limited tract in Western India, that he had never seen the vast majority of Indian formations, and that he was compelled to take the whole of his description from other writers.

The rocks of the Indian Peninsula are classed by Dr. Carter in 13 sub-divisions: (1) The Primitive Plutonic Rocks; (2) Older Metamorphic Strata; (3) Secondary Plutonic Rocks; (4) Cambrian and Silurian Rocks of M'Clelland; (5) Oolitic Series; (6) Cretaceous System; (7) Eocene Formation; (8) Volcanic Rocks (Trappean System, first series); (9) Inter-trappean Lacustrine Formation; (10) Volcanic Rocks (Trappean System, 2nd series); (11) Miocene and Pliocene Formations; (12) Post-pliocene Period; (13) Recent Formations. This classification is inferior in accuracy to Captain Newbold's. It was an unfortunate mistake to class the Gondwána rocks with the Transition and Vindhyan formations; but it was still more erroneous to call the latter "oolitic." Dr. Carter, depending upon

the descriptions, tried to classify the different deposits of his "Oolitic series" in three groups, termed respectively Tara, Kattra, and Panna, from localities in Bundelkhand, and much confusion has hence arisen. The classification of the metamorphic rocks also is artificial; and the subdivision of the volcanic rocks into two series, the intercalation of the intertrappean lacustrine series between the two, and the position assigned to the eocene rocks below, instead of above the traps, have all proved to be incorrect. Even where Dr. Carter was personally acquainted with the rocks, his views have not always been confirmed by subsequent research. Thus the traps of Bombay and Salsette were classed as intrusive; whereas almost all other observers agree in considering these beds as resting regularly, with their intercalated sedimentary beds, upon the older lava flows of the Deccan; and there can be no doubt that this is the correct view, the dip of the Bombay beds being due to disturbance after their consolidation.

Attention is called to these grave errors in Dr. Carter's paper from no wish to criticise his work harshly, but because, owing to the numerous merits of the "Summary," his views have been widely accepted, and are still quoted as valid in recent works: for instance, in Dr. Leith's description of the geology of Bombay, just published in the *Bombay Gazetteer.* In many respects Dr. Carter's Summary was a most valuable compilation; and, with the exception of the mistake about the rocks of Bombay, all the errors were due to the imperfection of the observations from which the work was compiled. The labour of compiling a general description of Indian rocks from the fragmentary materials available at the time was very great; and by the compilation of his Summary, by the republication of the various geological papers on Western India, and by the collection of numerous valuable notes in the Journal of the Bombay Branch of the Royal Asiatic Society, Dr. Carter gave most important aid to Indian geology.

Greenough, 1854.—Mr. Greenough's Geological Map of India was exhibited to the British Association in 1854, and published shortly after. The author had endeavoured to combine all published information as to the distribution of Indian geological formations; and the result was a map which did represent fairly the areas occupied by some of the principal formations, such as the metamorphic rocks and the Deccan trap; but which, owing to the very imperfect knowledge available at the time, was deficient in details, even with respect to those formations, and which contained many errors both in topography and the distribution of the rocks. Still the map, although it does not quite represent the knowledge available at the time of its publication, is a very valuable record of the amount

procurable by a careful recorder working in Europe. In presenting the map to the British Association, Mr. Greenough gave a brief sketch of the rocks known to occur in India. This sketch will be found at page 83 of the transactions of the sections, in the Report of the Twenty-fourth Meeting of the British Association, published in 1855.

Later sketches.—Although the date of publication of the last two works, Carter's Summary and Greenough's Map, is posterior to that of the commencement of regular survey operations under the late Dr. Oldham, the work of surveying had commenced too short a time for the results to be appreciable; and the description and map named represent, the former more adequately than the latter, the knowledge of Indian geology existing when systematic surveying was commenced. Surveys of isolated tracts had previously been made by Captain Herbert, Mr. Williams, Dr. M'Clelland, Dr. Fleming, and others for Government; but the regular examination of the country can scarcely be said to have commenced before 1851, if indeed its origin should not be placed somewhat later. The only general descriptions since published are by various officers of the Survey. A digest of the geological information published up to the time was printed by Professor Martin Duncan for the use of students at Cooper's Hill College, but was not published. A brief sketch of Indian geology was given in Mr. H. F. Blanford's "Rudiments of Physical Geography for the use of Indian Schools." Lastly, whilst the present work has been passing through the press, Dr. Waagen, who, like Mr. H. F. Blanford, belonged formerly to the staff of the Indian Geological Survey, has published a short general description of the geology of India, entitled "Ueber die geographische Vertheilung der fossilen Organismen in Indien" in the "Denkschriften" of the Imperial Academy of Sciences, Vienna. All these papers are founded, like the present work, on the survey observations, and consequently require no detailed notice.

List of European formations.—In the following pages it will often be necessary to refer to particular beds in Europe. The following is a list, arranged in the accepted sequence, of the groups and minor formations, in England, France, Germany, and some other parts of Europe, most commonly referred to in geological works. The list is taken in great part from that in Lyell's Elements of Geology, but is shorter; whilst a few formations, important for the correlation of Indian rocks, are added, and a few foreign terms. The omission of all mention of a group in any column by no means indicates the absence of the formation in the country to which the column refers, nor are the groups noted necessarily exact equivalents of each other.

		Great Britain and Ireland.	France and Belgium.	Germany, Austria, Switzerland, Italy, &c.	
Post-tertiary or Quaternary.	*Recent* ...	Newer alluvial gravels. Peat mosses, &c.	Terrain moderne (D'Archiac).	Alluvium, &c.	
	Pleistocene.	Cave deposits. Glacial drift.	Terrain quaternaire ou diluvien (D'Archiac). Formation erratique.	Diluvium. Loess of Rhine, &c.	
Pliocene ...	*Newer* ...	Boulder clay and older glacial drift. Norwich crag.			Neocene (Neocän) or Neogene.
	Older ...	Red crag. Coralline crag.	*Subapennin.* Antwerp crag.		
Miocene ...	*Upper* ...	*Wanting.*	*Falunien.* Faluns of Touraine and Bordeaux.	Beds of Vienna basin. Marine Mollasse of Switzerland.	
	Lower ...	Hempstead beds.	Calcaire de la Beauce. Grès de Fontainebleau.	Beds of Mayence basin. Brown coal of Northern Germany. Lower Mollasse of Switzerland.	Oligocene (Oligocän).
Eocene ...	*Upper* ...	Bembridge, Osborne, and Headon beds. Barton beds.	Gypsum of Montmartre. Calcaire silicieux. Grès de Beauchamp ou Sables moyens. *Parisien.*	Flysch of Alps.	
	Middle ...	Bracklesham beds and Bagshot sands.	Calcaire grossier. Lits coquilliers. *Parisien.*	Nummulitic limestone.	
	Lower ...	London clay. Woolwich and Reading beds. Thanet sands.	*Suessonien.* Argile plastique. Sables de Bracheux.	Ronca beds.	

CRETACEOUS ...	Upper ...	Upper white chalk with flints ... ... Lower white chalk ... ... Chalk marl ... ... Upper greensand ... ... Gault ... ... Blackdown beds	Danien: Maestricht beds: craie pisolitique. Senonien: craie blanche. Turonien: craie tufau: craie chloritée. Cenomanien: grès vert: Tourtia. Albien.	Gosau beds. Pläner. Hippuritic limestone. Quader.	
	Lower ...	Lower greensand. Specton clay. Weald clay. Hastings sands.	Aptien. Neocomien.	Hils conglomerat. Hilsthon. Wealden of Hanover.[1]	
JURASSIC ...	Upper ...	Upper oolite. Purbeck beds ... ... Portland stone and sand ... Kimmeridge clay	Portlandien. Kimmeridgien.	White Jura or Malm. Solenhofen beds.	
		Middle oolite. Coral rag ... ... Oxford clay ... ... Kelloway rock	Corallien. Oxfordien. Callovien.		
	Middle ...	Lower oolite. Cornbrash and forest marble ... Bath or great oolite ... ... Stonesfield slate ... ... Inferior oolite	Bathonien. Bajocien.	Brown Jura or Dogger.	
	Lower ...	Lias. Upper lias ... ... Shale and limestone ... ... Middle lias or marlstone ... Lower lias	Toarcien. Liasien. Sinemurien.	Black Jura or lias; Hierlatz beds.	
TRIASSIC ...	Upper ...	Rhætic, Penarth or *Avicula contorta* beds ...	... ...	Dachstein limestone. Kossen beds.	Rhætic.
		Upper new red sandstone. Red shales with rock-salt. Dolomitic conglomerate of Bristol.	Saliferien. Marnes irisées.	Haupt dolomit and Raibl beds. Lettenkohle. Hallstatt beds. St. Cassian beds.	Keuper.
	Middle ...	Wanting.	Conchylien.	Muschelkalk. Wellenkalk.	
	Lower ...	Lower new red sandstone (part).	Grès bigarré.	Bunter sandstone.	

[1] By many German geologists the Wealden is classed as Jurassic.

		Great Britain.	France and Belgium.	Germany, Austria, Switzerland, &c.
Permian or Dyas		Lower new red sandstone (part). Magnesian limestone and marl slate of Durham, &c. Trappean, breccia and red marls.	*Permien* or *Pénéen*. Grès des Vosges.	Zechstein. Kupferschiefer. Rothliegendes, or Rothes Todtliegendes.
Carboniferous ...	Upper ...	Coal-measures of England and Wales. Millstone grit. Yoredale series of Yorkshire.	*Carbonifèrien*. Terrain houillier.	Steinkohl system.
	Lower ...	Mountain limestone. Lower coal-measures of Scotland. Lower limestone shale or carboniferous slate.		Culm.
Devonian ...		Old red sandstone. Sandstones of Dura Den. Yellow sandstones of Ireland. Petherwyn group of Cornwall. Pilton, Ilfracombe and Lynton groups of Devonshire.	*Devonien*.	Grauwacke. Limestone of Eifel.
Silurian ...	Upper ...	Upper Ludlow and Downton limestone with bone bed. Aymestry limestone. Lower Ludlow. Wenlock limestone and shale. Woolhope limestone and grit. Upper Llandovery or May Hill sandstone. Lower Llandovery slates.	*Silurien*.	......
	Lower ...	Bala or Caradoc beds. Llandeilo flags. Arenig or stiper-stones group.		
Cambrian ...	Upper ...	Tremadoc slates. Lingula flags.	......	Premordial zone of Bohemia.
	Lower ...	Menevian beds. Longmynd group. Harlech grits and Llanberis slates.		
Laurentian ...	...	Fundamental gneiss of Hebrides.	......	......

Classification of animal kingdom.—For purposes of reference, and as a key to some of the lists of fossils, the following table, shewing the arrangement of subkingdoms, classes, subclasses, and orders of animals, may be useful. The system is that of Professor Huxley, as proposed in his "Introduction to the Classification of Animals."

Subkingdoms.	*Classes.*	*Orders.*
I. VERTEBRATA	1. MAMMALIA	Primates.
		Insectivora.
		Chiroptera.
		Carnivora.
		Rodentia.
		Proboscidea.
		Hyracoidea.
		Ungulata.
		Cetacea.
		Sirenia.
		Edentata.
		Marsupialia.
		Monotremata.
	2. SAUROPSIDA (*a*) *Aves*	Saururæ.
		Ratitæ.
		Carinatæ.
	(*b*) *Reptilia*	Crocodilia.
		Lacertilia.
		Ophidia.
		Chelonia.
		Ichthyosauria } Enaliosauria.
		Plesiosauria } Enaliosauria.
		Dicynodontia.
		Pterosauria.
		Dinosauria.
	3. ICHTHYOPSIDA (*a*) *Amphibia*	Urodela.
		Batrachia.
		Gymnophiona.
		Labyrinthodonta.
	(*b*) *Pisces*	Dipnoi.
		Elasmobranchii.
		Ganoidei.
		Teleostei.
		Marsipobranchii.
		Pharyngobranchii.
II. MOLLUSCA	1. CEPHALOPODA	Dibranchiata.
		Tetrabranchiata.
	2. PTEROPODA.	
	3. PULMOGASTEROPODA or *Pulmonata*.	
	4. GASTEROPODA (*Branchiogasteropoda*).	
	5. LAMELLIBRANCHIATA (*Pelecypoda*).	
III. MOLLUSCOIDA	1. ASCIDIOIDA	Branchialia.
		Abdominalia.
	2. BRACHIOPODA	Articulata.
		Inarticulata.
	3. BRYOZOA or *Polyzoa* (*Ciliopoda*).	Phylactolæmata.
		Gymnolæmata.

Subkingdoms.	*Classes.*		*Orders.*
IV. CŒLENTERATA	1. ANTHOZOA or *Actinozoa*		Ctenophora. Coralligena.
	2. HYDROZOA		Hydrophora. Siphonophora. Discophora.
V. ANNULOSA or *Articulata.*	1. INSECTA	ARTHROPODA.	Coleoptera. Hymenoptera. Lepidoptera. Diptera. Hemiptera. Strepsiptera. Trichoptera. Neuroptera. Orthoptera.
	2. MYRIAPODA	ARTHROPODA.	Chilopoda. Chilognatha.
	3. ARACHNIDA	ARTHROPODA.	Arthrogastra. Araneina. Acarina. Arctisca or Tardigrada. Pycnogonida. Pentastomida.
	4. CRUSTACEA	ARTHROPODA.	Podophthalmia. Branchiopoda. Ostracoda. Pectostraca. Stomapoda. Edriophthalmia. Merostomata. Copepoda. Trilobita.
	5. ANNELIDA		Chætophora. Discophora.
	6. CHÆTOGNATHA.		
VI. ANNULOIDA	1. SCOLECIDA		Trematoda. Tæniada. Turbellaria. Acanthocephala. Nematoidea. Rotifera.
	2. ECHINODERMATA		Echinidea. Holothuridea. Asteridea. Ophiuridea. Crinoidea. Cystidea. Edriasterida. Blastoidea.
VII. INFUSORIA	1. INFUSORIA.		
VIII. PROTOZOA	1. SPONGIDA or SPONGIOZOA.		
	2. RADIOLARIA (including *Polycistina*).		
	3. RHIZOPODA (including *Foraminifera*).		
	4. GREGARINIDA.		

MANUAL OF THE GEOLOGY OF INDIA.

CHAPTER I.

PENINSULAR AREA.

AZOIC ROCKS—GNEISSIC OR METAMORPHIC SERIES.

Introductory remarks:—Three-fold division of azoic rocks — Three gneissic regions — Main region, south and east, including Assam — Bundelkhand region — Arvali region — A key section — General composition and distribution of azoic rocks. Bundelkhand gneiss: Composition of the gneiss — The schists — Granitic veins — Quartz reefs — Trap dykes — Accessory minerals — Contiguous formations. Main gneissic region: Bengal area — Singhbhum area — Orissa area — Central Provinces — South Máhratta area — The Southern Konkan — The Wainád — The Nilgiris — Trichinopoli and Arcot — Assam area. Arvali.

Introductory remarks.—In most countries the disappearance of organic remains is gradual, as we descend in the series of stratified formations. The rocks become more and more altered, by compression and chemical transformation, from their original condition as sediments, and the organic forms they once enclosed have thus been obliterated. This general fact makes way for the opinion now prevalent—that the oldest known fossils are the descendants of forms for ever lost to observation. In India, as a rule, there is a very abrupt contact between the most ancient rocks which have been so much altered as to have become uniformly crystalline and other very ancient formations which have undergone comparatively little change; showing that the former had already been metamorphosed when the latter were deposited. There are also, in this country, some cases of gradual transition between the crystalline metamorphic rocks and the slightly affected strata of adjoining areas. We have, however, to pass through many upward stages of transition rocks, and to cross a great hiatus in the ascending sequence of formations, before we meet with the first trace of life in Peninsular India.

In most countries, again, great gaps, such as that just alluded to, occur in the succession of stratified rocks. These breaks in the geological record are most surely indicated by a more or less complete change in the fossil contents of the deposits above and below them. The names

of the main divisions in the geological scale of formations—the palæozoic, mesozoic, and cænozoic—originated in this way. But very generally these stratigraphical horizons are also well defined by a strong contrast in the arrangement and distribution of the preceding and succeeding strata, constituting what is called *unconformity* of the deposits so related. There is a most marked relation of this kind between the fossiliferous and the azoic formations in India. The unconformity is so complete that the oldest beds of the upper series occur nowhere in contact with the younger members of the lower, thus showing that a total change in the physical geography of the region was effected in the interval between the two, and that the duration of that interval must have been great. Unfortunately, the want of fossils in the lower series deprives us of all such means of comparing them with the rocks of other countries as would enable us to determine the magnitude of the break by the scale usually employed; a scale of which the divisions are marked by a known succession of organisms.

Several of the upper groups of the azoic series, of great thickness, and covering immense areas, are quite undisturbed and chemically unaltered; so there is no ground for supposing that their fossils have been obliterated. They comprise, moreover, a great variety of rocks—sandstones, shales, and limestones—and many phases of deposition, thick and thin layers, often with beautifully defined ripple, and rain-markings. As yet, however, they have yielded no fossils, although very large areas have been closely searched. We are to this day ignorant whether the highest of our azoic rocks, the Vindhyan series, are contemporaneous with any fossiliferous palæozoic group, or whether they are older than all rocks in which organic remains have hitherto been found. It is one of the puzzles and disappointments of Indian geology, for we must believe that the discovery will some day be made. This faith is not solely based upon the inference already stated, that life upon the globe was immensely antecedent to the oldest known fossils; there are also positive facts to support it:—we cannot, indeed, assign a period for the lapse of time between the azoic and the first fossiliferous deposits of this region, but it is certain that the first fossil forms in these latter are already more than half-way up in the known scale of life-progression, the greater portion, if not the whole, of the palæozoic era being unrepresented by fossiliferous deposits; and we know, from instances elsewhere of barren rocks overlying fossiliferous strata, that unfossiliferous deposits have been locally formed while life was abundant on the earth. The explanation of such facts is still obscure, there being no trace, in these barren deposits in India, of any ingredient prejudicial to life.

From the facts mentioned, we may surmise that an indigenous school of geology in India would probably have held very strict doctrines upon an absolute abrupt commencement of life upon the globe.

Three-fold division of azoic rocks.—It is thus evident that the term *azoic* is applied here in a merely negative and provisional sense. The word affords, for the present, a convenient collective designation for an immense series of rocks, more or less related in sequence, which have to be described connectedly, and which are totally severed stratigraphically from all the later formations of this great geological region. The base of the azoic series is the gneiss, the top is the Vindhyan formation, and between the two there are several well marked groups, or series, of deposits, having a great aggregate thickness. Some of these have certain characters in common, even at great distances apart, suggesting their close equivalence in time. It would simplify classification and description to assume this identity, and to stamp them with a common name, but these trenchant devices only end in complicating matters, and making final adjustment more difficult. It will be better to speak of all these intermediate groups as the transition formations, distinguishing the several sub-divisions as belonging to particular areas, or basins, and noting the relations of resemblance and of difference between them. We have thus the following three great systems of azoic rocks in Peninsular India:—

3,—Vindhyan.
2,—Transition or submetamorphic.
1,—Gneissic or metamorphic.

The areas occupied by these three divisions of our primary rocks are very unequal. More than half of Peninsular India is taken up by the gneissic series; and the Deccan trap, a comparatively modern formation, which is the next most widely spread rock of this region, is probably throughout a large part of its extent underlaid by gneiss.

Three gneissic regions.—In spite of the numerous interesting problems presented by the metamorphic rocks of India, and although the area composed of these formations exceeds that of all other groups together, the study of the crystalline strata has necessarily been deferred by the Geological Survey until our knowledge of the newer formations is more advanced; and consequently we still know but little of the former except in the neighbourhood of the latter. It is presumable that, within the immense area of crystalline rocks exposed in India, there are, as elsewhere, metamorphic representatives of several groups of strata of different geological age; but we can at present only indicate three sub-divisions which have more than superficial value. These sub-divisions

are probably to some degree distinct in geological age, and they occupy three distinct areas of very unequal extent.

Main or Eastern area.—With the exception of a narrow strip of overlying strata in the basin of the Godávari, connecting the eastern sea-board with the spread of the Deccan trap, gneissic rocks extend without a break from Cape Comorin to Colgong on the Ganges, at the north-east corner of the rock-area of the Peninsula. The distance in a straight line is 1,400 miles, and the mean breadth of this gneissic tract is about 350. This immense expanse of ground, with a few inliers exposed by the removal of covering strata in midland India, must form one of the divisions indicated, the interruptions to continuity being only superficial. For the same reason we must place in this natural group the gneissic rocks forming the basis of the Shillong plateau and Lower Assam. Although separated from the Peninsula by a gap of 150 miles, through which the Ganges and Bráhmaputra pour their waters, this now isolated mass undoubtedly belongs to the original *terra firma* to which the later mountain-systems of the Himalaya and of Burma have since been added. It is, moreover, recognisably related to the main gneissic area of Hindustan.

The interruptions to this main gneissic area are only superficial, and consist of patches of much younger strata resting upon, or faulted into, the fundamental rock. It is otherwise with the separation between the main area and the gneiss of Bundelkhand. This break is connected with one of the leading structural characters of the region, one that still affects the features of the country in a very marked way, but that dates from the azoic period, and in which the gneiss itself took part. The zone of separation is about 90 miles wide; and it is here that we find the fullest section of the upper azoic series, both transition and Vindhyan. A band of schists, slates, and quartzites fringes the main gneissic area on the north, and extends in a steady west-south-west direction from Manghir (Monghyr), near the north-east extremity of the gneiss in Bengal, at first along the south margin of the alluvial plains of the Ganges, then up the Son (Soane) valley, whence it crosses continuously into the Narbada (Nerbudda) valley, and down the latter to Barwai (Burwye), where the basaltic formation stretches across between the Deccan and Malwa plateaux. From the Gangetic plains to the spot where they disappear beneath the Deccan traps, the transition rocks are in contact on the north with the Vindhyan formation of the Bundelkhand and Malwa plateaux.

On the extension of the same line to the east-north-east we find a corresponding band of schists and quartzites, similarly related to the gneiss of the Shillong plateau.

Bundelkhand area.—To the north of the Vindhyan plateau in Bundelkhand, there is a compact semi-circular area of gneiss. On the north-north-east face, for 200 miles, along the chord of the arc, the gneiss is gradually overspread by the Gangetic alluvium, and round the convex southern margin, the metamorphic tract is bounded by a scarp of Vindhyan sandstones. At many points along the south-east side of the arc, there are narrow outcrops of the transition formations, recognisably the same as those of the Son and Narbada valleys. We thus have the means of comparing the relations of the gneissic rocks of the two areas, and the result is very significant. Formations that rest undisturbed, unaltered, and almost horizontal on a denuded surface of the Bundelkhand gneiss, are uniformly disturbed, metamorphosed, and subject to granitic intrusion in the gneissic region of the main crystalline area. This is almost conclusive evidence that some, at least, of the latter is of later date than the gneiss of Bundelkhand, which will therefore take precedence in order of description as the oldest known rock of India.

Arvali area.—In the north-western quarter of Peninsular India there is a third independent area of crystalline and transition rocks. The Arvali (Aravulli) ranges are formed of them, and their name may be conveniently used to designate this geological region. To the south-west it extends into Guzerat, and to the north-east the ranges reach as far as Delhi. It is separated from the Bundelkhand area by 70 miles of Vindhyan rocks, which stretch up to near Agra, and form a broad structural barrier like that to the south-east. Here, too, some of the lower formations can be identified on both sides of the barrier, but the base-rocks are badly exposed, and the ground has been but very partially examined. In one or two spots near Alwar (Ulwur) a fundamental gneiss seems to be unconformably covered by the schists and quartzites of the Arvali system; but these latter have not been identified with the transition groups of Bundelkhand; so there is no clue as yet to the relative ages of the two gneissic groups of Arvali and Bundelkhand.

The separation of the Arvali crystalline region from that of Eastern India is not so distinct. Only 50 miles of a covering formation (the Deccan trap) intervenes between the schists already mentioned as seen in the Narbada valley near Barwai, and the extreme eastern inliers of the Arvali crystallines about Bágh. The rocks in both positions are, moreover, very similar in composition and metamorphic condition, but it has been observed that a different direction of the structural features (cleavage and foliation) obtains in the western area. This is an important character in the discussion of highly disturbed formations, and shows that the distinction of the two regions is not purely superficial, arbitrary,

or geographical. It is, moreover, evident that the main basin of transition rocks, if extended to the south-west beneath the overlying trap, must intervene between the Arvali and the south-eastern gneissic regions.

A key section.—Before noticing the few particulars known regarding each area and the several members of the azoic series, it will be well to get a general idea of their relations by a brief discussion of a diagrammatic section taken in a north-west to south-east direction across the Bundelkhand gneiss, and prolonged as far as the eastern gneissic area on one side and to the Arvali gneiss on the other (see figure). All the features represented are not found on a single straight line, but each is taken from the zone in which it appears on the section. The distance is about 350 miles, and the figure is, of course, very much distorted, but it will afford assistance in understanding the features.

Three distinct formations are found in contact with the Bundelkhand gneiss along its south-eastern margin. The lowest is well seen in the Bijáwar State, and it was first described under the name of Bijáwar.[1] Its relation to the fundamental rock is locally very clear: its bottom beds rest flatly upon an irregularly denuded surface of the gneiss, and mantle round the anciently weathered outcrops of the quartz-reefs which traverse the latter. Thus, the break between the gneiss and Bijáwars is

Diagrammatic section from Alwar to South Rewah.

a'', *Gneiss, Bengal.* *b''*, *Lower Transition, Arvali.* *c*, *Upper Transition, Gwalior.*
a', " *Arvali.* *b'*, " " *Bijáwar.* *d'*, *Upper* } *Vindhyans.*
a, " *Bundelkhand.* *b*, " " *Slates.* *d*, *Lower* }
e, *Gondwana.*

[1] Mem., G. S. I., Vol. II, pp. 6-35.

total. The latter formation thickens rapidly to the south-east, and the beds in this direction exhibit considerable disturbance and some metamorphism. The Bijáwars are overlaid by very different strata, which have been locally described as the Semri group, from the river of this name, in which they are well exposed.[1] They, too, thicken to the south-east and have been moderately disturbed, but show no sign of metamorphism. In places they quite overlap the Bijáwars and rest directly on the gneiss. It would seem that this extinction of the Bijáwars is, at least to some degree, an original thinning out, and that they never extended indefinitely over the crystalline area. In their turn the Semris are overlaid and over-lapped by the Vindhyan formation, outliers of which cap hills of gneiss beyond the margin of the sedimentary basin.

On crossing to the south-east of the Vindhyan plateau, we find some important changes in the relations of the underlying rocks. The equivalents of the Semri beds are fully identified in the Son (Soane) valley. Here, again, there is no contact-unconformity between them and the Vindhyans, but there is the most complete break possible between them and an underlying series, part of which, at least, corresponds with the Bijáwar beds. Intrusive granitic masses are found in the Bijáwars, but do not penetrate the bottom beds of the Son series, which not only repose horizontally on denuded surfaces of both the Bijáwars and the granite, but extend in places on to the gneiss of the eastern region. These features imply a break of immense duration between the Son and the Bijáwar series, and establish on this horizon a main division in our azoic system. The other important contrast between the sections in the Son valley and in Bundelkhand is, locally at least, the complete metamorphic transition between the Bijáwars and the gneiss. They must have together undergone disturbance and metamorphism. If, then, we are correct in taking the transition rocks of the two localities to be Bijáwars, on the same geological horizon, this contrast of conditions involves a much younger age for the Bengal gneiss, or for some portions of it.

From the section sketched in the last paragraph we obtain the main outline of our azoic series: gneiss of two ages, a transition formation, and a well separated upper series. It will be convenient to speak of the Semri and Son deposits as Lower Vindhyans; for, although by no means co-extensive with the Vindhyans proper, even in this basin, they are everywhere conformable to them throughout a very extensive area.

By continuing the section to the north-west, we are able somewhat to expand the general series. All round the western edge of the Bundelkhand gneiss the upper Vindhyans are the covering rock, but at the

[1] Mem., G. S. I., Vol. II, p. 6.

north-west corner of the crystalline area a new formation crops out to the eastward from beneath the Vindhyans, and forms a north boundary to the gneiss. This, which is known as the Gwalior formation, is unconformable both to the gneiss and the Vindhyans; it rests at a gentle inclination upon the former, and its surface has been deeply eroded before the deposition of the latter, the bottom beds of which are largely made up of Gwalior debris. The Gwaliors have undergone but little disturbance and no crystalline metamorphism.

Judging from the presumptions afforded by these stratigraphical features, we have here a formation intermediate between the lower Vindhyans and the Bijáwars, a representative of the great break which has been shewn to exist between these two series in the Son region. The lithological characters would support this conjecture, which is further borne out by the fact that far away in Southern India we find a formation (the Karnul) resembling the lower Vindhyans and resting unconformably upon another group (the Kadapah) which has a great resemblance to the Gwaliors, and which there, too, is quite unconnected with the gneiss. If we might adopt total severance from the gneiss as a criterion in our main classification, it would be better to bring the Gwaliors and their equivalents into our general nomenclature as lower Vindhyans, and to convert those now so designated into middle Vindhyans (or to introduce some new class-name in this sense); but it is safer for the present to postpone any attempt at a permanent classification, and so we may let the Gwaliors and their allies stand in our scale as upper transition groups.

After crossing the northern arm of the great Vindhyan basin in a north-west direction from Gwalior, the change to the Arvali region is abrupt. The boundary is mostly faulted, the horizontal beds of the upper Vindhyans abutting against the fault, close beyond which a few outliers occur of Vindhyan rocks, and with some of them Gwaliors are associated, both being more or less vertical. Away from the boundary (to the westward) we only find formations of a different type, which have been described as the Arvali series. They are greatly disturbed and altered, and their relation to the underlying rocks is very puzzling. Locally they rest abruptly upon a massive granitoid gneiss;[1] elsewhere they are associated at the base with an arkose or pseudo-gneissic rock which is locally difficult to distinguish from the true gneiss.

These are difficulties for which we shall have to notice a parallel in the Bijáwar area itself and in Behár, so the Arvali rocks may probably be ranked with the lower transition groups as already defined. But a further

[1] It is doubtful whether some of this is not intrusive granite.

difficulty meets us: in the same region these Arvali strata rest upon the edges of a schistose slate formation (see section) which must, of course, be an older member of the transition series. The ground in which these rocks occur has, however, been so little examined, that any views now expressed must be considered as open to much correction.

General composition and distribution of azoic rocks.—It is only in the most general way that any common characters can be established amongst rock-groups so widely scattered, so doubtfully affiliated, and so little studied.

The following general classification will show the plan to be followed in describing the various sub-divisions. Like all such tabular arrangements in the present work, the formations are grouped in descending order, but in describing them it will be more convenient to commence with the lower groups:—

III—VINDHYAN	*Upper*	Comprising in descending order the Bhánrer (Bundair), Rewah, and Kaimúr (Kymore) groups. Sandstones and shales greatly predominate, whilst limestone occurs as a subordinate member in the upper group. Only known in the great northern basin, extending from Sasseram to Nimach (Neemuch) and Agra.
	Lower	Son, Semri, Bhima, and Karnul groups, all more or less equivalent to each other. Limestones, sandstones, and shales are generally distributed. Found in several basins, the principal of which, commencing at the north, are (1) the great northern or Vindhyan basin, on both sides of which lower Vindhyans crop out; (2) the Chhattísgarh area, extending south to Bastar, in proximity with several scattered tracts in the valleys of the Pem, Pranhíta, and Godávari rivers; (3) the Bhima; and (4) the Karnul basins.
II—TRANSITION *or* SUB-METAMORPHIC	*Upper*	Gwalior, Kadapah, and Kaladgi representative groups. Quartzites or sandstones, slates or shales, with limestone, jasper or iron bands and interbedded trap. The principal basins are those of (1) Gwalior, (2) Kadapah, and (3) Kaladgi.
	Lower	Arvali, Bijáwar, Champanir, and Maláni groups. Slates, more or less schistose, and quartzites in about equal proportions, with locally associated limestone and contemporaneous trap. The Maláni group is volcanic. There are two principal regions, (1) the Arvali, and (2) the interrupted areas in the Narbada and Son valleys, Bundelkhand and Behár, with detached area in north-east Bengal, all of which must be described as parts of the same tract. There is also a large area of these rocks in south-west Bengal, besides some minor exposures, which cannot even be indicated on the map.
I—GNEISSIC *or* METAMORPHIC		Three sub-divisions, Arvali, main or eastern area, and Bundelkhand, the latter being older than the others. Gneiss, schist, and other forms of crystalline metamorphic rocks with intrusive granitic veins. The regions correspond to the sub-divisions.

Bundelkhand gneiss.—The gneiss of Bundelkhand takes precedence in order of description, being the oldest, so far as now known, in India. It forms the basis of lower Bundelkhand as distinguished from the higher portions of that district lying on the adjoining Vindhyan plateau. On the north-north-east border, for 200 miles, the gneiss is gradually covered by the superficial deposits forming outlying and marginal portions of the Gangetic plains, at an elevation of 500 to 600 feet above the sea. Elsewhere the area is very sharply bounded by a scarp of overlying formations, whether Vindhyan or transition. Along the base of the scarp to the south-west the elevation varies between 1,000 and 1,200 feet above the sea, the scarp itself rising to 1,900. The gneiss sometimes forms hills, but the general features of the ground are flat, undulating uplands, sparsely cultivated, including shallow valleys and plains of alluvial land. All over lower Bundelkhand long narrow serrated ridges composed of quartz-reefs form a most striking feature of the landscape. They run in straight lines, generally with a north-east to south-west direction, and sometimes attain an elevation of 600 feet over the surrounding country.

Composition of the gniess.—Gneiss is by far the commonest rock.[1] It may be described as consisting of some six minerals—red orthoclase felspar, a white plagioclastic (triclinic) felspar (probably oligoclase), quartz, hornblende, chlorite, and mica. In any one place the gneiss may contain only two of these, or it may include all of them. With regard to texture, every variety is met with, from a homogeneous felstone, in which no individual mineral can be distinguished, even with a lens, to a coarsely porphyritic rock, including felspar crystals more than two inches long. The orthoclase nearly always forms the main mass, and exceeds in quantity all the other minerals together. Its ordinary colour is a darkish red, but now and then it is much paler, and almost or quite white. In such cases, when both felspars occur, it is not easy to distinguish them on a fresh fracture, but the difference becomes apparent on a weathered surface. One (the orthoclase) has a vitreous, or somewhat pearly, lustre and translucent aspect; the other is dull and quite opaque, having been superficially altered into kaolin. The plagioclastic felspar is a comparatively uncommon mineral; when present, it plays quite a subordinate part, and occurs in much smaller crystals than the orthoclase. As often as not, no free quartz can be detected in the gneiss, and it very rarely indeed occurs in large quantity. The rock is usually hornblendic, but sometimes the hornblende is partially or entirely replaced by chlorite

[1] The characters of the rocks of this area are chiefly taken from the unpublished reports of Mr. F. R. Mallet.

and mica. The mica occurs of varying colours and of more than one species, both uniaxial and biaxial—green, brown, black, and silvery-white, the last being rare, and chiefly found in the southern part of the area.[1]

Foliation is seldom well developed, the rock being very commonly to all appearance perfect granite. No direct evidence has, however, been obtained beyond this, of the existence of true plutonic granite; and sometimes by close examination traces of foliation may be detected in

[1] The mode of grouping of these minerals will be best illustrated by a few particular examples of the common and the rare kinds. The ingredients are generally mentioned in the order of their prominence in the compound.

The hill at Pahári (10 miles north-north-east of Kirwi (Kirwee), is of coarse red-felspar-gneiss, with specks of dark-brown mica and a small proportion of quartz; through this rock small masses occur, from an inch to a foot in size, of a very fine-grained, more micaceous variety. The gneiss is intersected by a few seams of pegmatite, red felspar, and quartz, the felspar much preponderating. The gneiss, in which no foliation is traceable, covers the hill in large rounded blocks.

At Bambai (2 miles north-west of Kirwi) some of the gneiss is hornblendic, and in one place it is composed of red felspar, hornblende, and epidote. At Subhápur (10 miles south-west of Kirwi) the gneiss is hornblendic, passing into very fine-grained and compact hornblende-rock; a little south of this, true hornblende-schist occurs. At Dongáho (6 miles west of Ajigarh) the gneiss is of a common variety—a very large proportion of red felspar in coarse crystals with some hornblende, no quartz being apparent to the eye. Throughout this rock there occur bands of similar composition to the above, but extremely fine-grained.

Near Telorna (10 miles east of Chhatarpur) the gneiss is highly syenitic, with red felspar in the usual large proportion. At one spot it was observed to contain red orthoclase, white plagioclase, hornblende, black mica, and quartz.

At Páli (5 miles south-west of Nowgong) the gneiss consists of pink felspar in large crystals, green felspar in much smaller crystals, and chlorite.

Between Punon and Torea (7 miles east of Mohangarh) is a dark brownish-red felstone in which the minerals cannot be distinguished. At Deorat Ghât, Rámpura, and Kungirpura (5 miles south-west of Mohangarh) the gneiss consists of dark red felspar, quartz, and chlorite, the latter in small quantity. The rock is deep red from the felspar, but there is a considerable amount of quartz, in some specimens exceeding the felspar and chlorite together. In the Jamni river at Hirápur the gneiss is both fine-grained and coarse. Irregular seams and masses of each variety are included in the other, showing that both are the same rock.

The gneiss on the north-west side of Gunchári (12 miles east of Lalatpur) is moderately coarse, and includes no less than six minerals; orthoclase, white felspar, quartz, black mica, chlorite, and hornblende. It is the only place in which so complex a mixture has been observed. In the stream just south of Sindwána (16 miles south-east of Lalatpur) the rock is composed almost wholly of white felspar (orthoclase?) and quartz. The rock between Ikona (5 miles east of Maraura) and Girai is nearly all white orthoclase, frequently with silvery mica. At Bikrampur (16 miles north-north-east of Tehri) and elsewhere, a variety of gneiss is found, consisting of large crystals of red orthoclase, their longer axes preserving a general parallelism, imbedded in a matrix of impure chlorite, probably an impalpable mixture of chlorite and quartz. About Shágarh the rock is close-grained and granitic, with felspar, both red and white, black and silvery white mica, the latter being specially prominent in the pegmatite veins.

rock which at first sight appears quite devoid of it. This foliation generally has an east-north-east direction, but varies to north-east and east-south-east. The planes are more or less vertical.

The schists.—The subordinate varieties of rock, all combined, are of very insignificant extent in comparison to the gneiss. One of the most prominent is hornblende rock. At Jumúni (16 miles east-north-east of Tehri) there is a band about 50 yards wide of almost pure hornblende, showing cleavage-faces of an inch to an inch and a half long. It contains a small amount of epidote, and also white felspar, the latter disposed in irregular seams, more or less connected with the foliation, which is obscurely seen. A similar rock occurs in the Sujnám stream, west of Sokári (15 miles east-south-east of Lalatpur), and again north-west of Barwar, on the Lalatpur-Chandéri road. Another well marked variety contains about equal quantities of hornblende and white or greenish-white felspar in crystals about an eighth of an inch long. It may be seen east and north-east of Bánsi (10 miles north-by-east of Lalatpur). This rock sometimes contains, in addition, an inconsiderable proportion of reddish felspar, quartz, and green mica, and very minute specks of iron pyrites. The hornblende-rock sometimes resembles trap very closely; parts of it are as fine-grained as the intrusive dykes of diorite or the overflowing basaltic trap, and it weathers into similarly rounded lumps; but this variety passes into a much coarser kind, in which the felspar and quartz are well separated. The most trappean-looking portions, moreover, contain thin strings and films of epidote, which have not been observed in the trap.

Besides the hornblende-rock, various forms of schist occur with the gneiss, comprising talcose, hornblendic, chloritic, quartzose and even argillaceous schist, and the combinations of these with each other. Mica schist has not been observed. Schists are of very rare occurrence in the gneiss generally, but all the above varieties are to be found in some force in the southernmost part of the area, in the Maraura region. This peculiarity of distribution is so marked that it was thought that the schistose strata might here be separable from the gneiss. The suggestion is much encouraged by the fact that the great quartz-reefs, elsewhere so prevalent in the gneiss, stop short of this ground. It has not, however, as yet been found possible to draw a line between the gneissic and the schistose sub-divisions. Gneiss of the usual type is still a prevalent rock in the schistose area, and is the most southerly rock seen at Sháhgarh. It seems, too, to be truly associated with the schists. We may perhaps at least infer that in this region we have the top of the gneissic series of Bundelkhand.

The only stratigraphical feature observable in the gneiss of Bundelkhand is near the Dhasán river, in the southern part of the area, and consists of a synclinal fold, about two miles wide, marked by the recurring outcrop of a very conspicuous, banded, iron and quartz rock, dipping north at Baréta and south at Barwar; at Gerár, on the same strike as the last-named, the rock is inverted. Signs of an obscure outcrop of the same rock were noticed some ten miles to the north; and again, the iron-ore worked at Dháowára, ten miles south of Orchha, is this banded rock. It is composed of thin alternate laminæ of hæmatite and quartz; the former has a metallic lustre, although more or less silicious; the quartz is red and white, some laminæ being jaspery, others somewhat arenaceous, with distinctly visible grains, the latter form being probably decomposed. This is a type of rock of frequent occurrence in different formations of the azoic series—in the gneiss of Southern India, and in several of the transition groups.

It is a noteworthy fact that over the whole of this large area of gneiss not a single bed of limestone has been detected.

Granitic veins.—Pegmatite veins, from a few inches to a foot or two in breadth, are very common. If these were intrusive, it might be expected that they would be somewhat uniform in composition irrespective of the nature of the surrounding rock; but it has been invariably observed that the felspar of the vein is the same as that of the rock adjacent, whether the latter is orthoclase or plagioclase, or includes both; the chief difference consists in the larger crystallization and in the usual absence of the third mineral (hornblende, etc.) in the veins. It is therefore presumable that the veins were formed by segregation at the time of the crystallization of the gneiss.

The almost total absence of accessory minerals in these rocks is remarkable.

Quartz-reefs.—The quartz-reefs, already mentioned as forming a conspicuous feature of this area, are exclusively confined to the gneissic series. They are pretty equally distributed over the ground, with the exception noticed in the southern region, which, moreover, lies right across the strike of the reefs to the north-east.

Out of 110 local observations (principally taken in the eastern region), many being of different parts of the same reefs, Mr. Mallet found that 76 had a strike between 20° and 80° east of north, their mean direction being north-36°-east. In some minor cases the strike is more north-north-west. Instances of bifurcation are occasionally seen. Sometimes the same reef is very unsteady; that at Mulgoah (20 miles south-by-east of Nowgong) twists from north-35°-east to north-5°-west.

The vein at Mau (Mow) (near Nowgong) is double, or rather two veins run parallel at about 100 yards apart; just south of the town they are thrown about 300 yards horizontally by a fault running west-20°-north. The breadth of the veins varies from a few feet up to 100 yards; the latter dimension was found by rough measurement in the reef west of Bagwa (20 miles east-south-east of Tehri). Some of them are traceable in a direct line for more than 60 miles, the local interruptions which occur being sometimes due to removal by denudation, sometimes to strangulation of the vein itself. Other reefs, again, though of full thickness and very prominent at the surface, are short, and end abruptly. There is a good case of this at Dehri (12 miles south-east of Tehri) where a broad reef, 300 feet high, is only about a mile long, no trace of it occurring in the gneiss to the north or south. The narrow gaps by which the minor streams in many places cross the reefs give peculiar facility for the formation of lakes, as a very short dam is often sufficient to pond back a large surface of water: many of the numerous artificial lakes in Bundelkhand are formed in this way.

The reefs are often affected by joint-planes, which sometimes give an appearance of horizontal bedding to the mass. When parallel with the direction of the reef itself, they suggest in a more puzzling manner the impression of a bedded mass. Now and then the quartz is much shattered. At Deokalli (20 miles east-north-east of Chhatarpur) and Bagpura (25 miles south-east of Tehri) samples might be taken for the Bijáwar hornstone-breccia, a description of which will be found on a subsequent page.

Owing to the metamorphic condition of the reefs themselves, foliation is often developed; and it usually extends to the contiguous gneiss, which is generally so amorphous. When the foliation in both rocks has the same direction as the reef itself, as is the case at Chetrai (5 miles south-east of Rájnagar) the quartz mass might be taken to be interbedded with the gneiss. Generally the foliation is oblique to the direction of the vein, while still the same as that of the gneiss.

Many of the reefs are of greyish white quartz. Frequently they contain a large amount of impure serpentine, and occasionally they are formed almost entirely of this material. The more northerly of the two ridges at Dallipur (10 miles north of Sháhgarh) is an example. At Rájápur (8 miles west-by-south of Kálinjar) a band of nearly black serpentine occurs, apparently a continuation of the quartz vein to the north. In many cases the gneiss is serpentinous for some distance on each side of a vein, there being no distinct separation between the two rocks. North of Patauri (25 miles east of Tehri) the gneiss near a quartz

vein is composed of red felspar, quartz, and serpentine. Serpentinuos gneiss has not been observed, except near a quartz vein. Steatite takes the place of serpentine in a few veins. At Kudunwára (20 miles south-south-east of Orchha) the rock consists chiefly of this mineral. Some of the steatite is pure and has been quarried. On the flank of a ridge south-west of Sikana (20 miles east-south-east of Tehri) a large mass of steatite is extensively worked.

From his observations, as above sketched, Mr. Mallet concludes that the reefs were probably formed before the metamorphism of the gneiss was accomplished.

Many of the quartz-reefs as well as the gneiss itself are traversed by more recent and much smaller veins of pure white quartz, the thickest not much exceeding one foot in breadth. They are very frequently crystalline and drusy in the centre, and they are always sharply distinct from the rocks they traverse. Their direction is very irregular.

Trap dykes.—The gneiss of Bundelkhand is also remarkable for being traversed by extensive trappean intrusions, none of which penetrate any of the younger formations. These dykes, of true igneous rock, are more numerous than the quartz-reefs, and exhibit nearly as much regularity in their course, their prevailing direction being about north-35°-west, so as to cut the reefs obliquely at an angle of about 70°. Some few run east of north, and due east. Many are of considerable size, a breadth of 100 feet being not unfrequent; some are much wider. They are often persistent for great distances. The commonest type is an extremely hard and tough close-grained greenstone (diorite), in which the hornblende and the white felspar are sometimes clearly separated. The rock often weathers into large rounded blocks without any tendency to exfoliation. The small dykes are of a more earthy texture.

It is very rare to find any intersections of the dykes and reefs that can be taken as conclusive of their relative age. It is not so uncommon to find a dyke running close up to a reef on both sides without cutting it; but such an occurrence might easily happen, although the reef were the older, as it may have offered a greater resistance to splitting. One good case of the converse carries much more weight. Mr. Mallet records such an occurrence at about half a mile west-south-west of Bhagwáho, where a quartz vein striking east-20°-north abuts against a strong dyke running west-20°-north, traces of the quartz being found also on the other side. But he considers the general argument from the condition of the two rocks to be independently conclusive: the trap has certainly not undergone metamorphism, whereas the reefs as certainly have.

Accessory minerals.—The great rarity of accessory minerals in these rocks has already been noticed. Mr. Mallet only mentions epidote sparingly in the hornblende rock; schorl in some of the small quartz veins of the Maraura region, small grains of ilmenite in some of the pegmatite veins, and strings of altered kyanite in the quartzose rock of Dhánkua hill (10 miles west-north-west from Tehri). Small pieces of galena have been sent from Jhánsi for analysis, but their locality is not known, and they may not have been procured from the gneiss. Iron ore has been extensively burrowed for at Dháowára, 10 miles south of Orchha; it is a decomposed earthy condition of the banded hæmatite and quartz. The absence of any trace or tradition of gold in connection with the quartz reefs is noteworthy. The steatitic rocks are quarried to be turned into plates and bowls; and a talcose quartz schist of the Maraura region is much used for quern-stones (handmills). The coarse porphyritic granitoid gneiss is a favourite stone for the pillar sugar-mills. The massive gneiss would make fine building stone, but it is only used as rubble; the natives mostly build their houses of brick, using the Vindhyan sandstone for more important edifices.

Contiguous formations.—The history of this comparatively small area of gneiss would be very interesting. It has served as a shore or a bed for each of the great adjoining formations. The Bijáwars and the Gwaliors lie upon its margin north and south, but no detached outliers of either are found within its border, so that it may have been a well elevated area at the period of their formation. The same may be said of the lower Vindhyan deposits. It is not so with the upper Vindhyans, of which the outliers are numerous and lie at considerable distances from the scarp of the basin. In the east these form a portion of an ascending slope, the base of the capping Vindhyan sandstone being higher in the outliers than in the scarp. But in the north-west it is curiously the reverse; the gneiss reaches high up all along the western scarp, but the outliers of Vindhyan sandstone to the eastward rest at the general level of the low country.

The next overlying formation is the Deccan trap, remnants of which are found on the low ground in the southernmost part of the area, and traces of the infra-trappean (Lameta) conglomerate occur more extensively in the same position. That this portion of the scarp-bounded area can have been so occupied, almost necessarily implies that the whole of the gneissic ground must, at the period of the Deccan trap, have had a configuration very like what it has now; and, the source of the eruptive rock being presumably to the south or south-west, the lava must have poured from the plateau to the low lands. In the Madanpur gorge

trap does, in fact, occur continuously from one level to the other, but its condition suggests no resemblance to a lava stream.

The main gneissic region.—The great gneissic area of Eastern India cannot now be described in any detail. Its limits will be best understood by an inspection of the map. Along its north-north-west margin the gneiss is intimately connected with the transition series. Their detailed boundary is very intricate, and the general relation of the two formations is obscure, although some individual sections are simple enough. The discussion of the relations between the gneiss and transition rocks must be deferred until the latter have been described, as it is impossible to enter into details without referring to the character of the upper series. The same plan of describing the relations between the groups when treating of the highest will be adopted in other cases also.

At the east end of the northern boundary the schists appear as detached and semi-detached ridges, the Gangetic alluvial plain reaching at many points up to the main gneissic area. In the small valleys draining northwards from the crystalline plateau, remnants are found of the bottom Gondwána deposits, showing to how great an extent the actual features of the metamorphic rock-mass are a reproduction of a very ancient surface; for it is certain that, in the interval between the lower Gondwána period and the present day, the superficial characters must have been very different from what they are now. Along the whole north-east border, for 80 miles, the Bengal gneiss passes under the Gondwána strata of the Rájmehál hills, not altogether owing to a general tilt of the surface, but partly to an original slope, for the successive groups of the series overlap each other on to the gneiss.

These hills being the most north-easterly point of the peninsular rock-area, it would seem as if the isolation of the gneiss of Lower Assam and the Shillong plateau might date from the Gondwána period; but against such a supposition there are objections that will be discussed elsewhere. Facts analogous to that just noticed in the Rájmehál hills occur at intervals along the whole east coast of the peninsula: the description of them belongs to the section of this work relating to the Gondwána system.

Little is known of the Malabár coast. The gneiss is probably nowhere far from the surface. From Malwán northwards it is replaced by the Deccan trap.

The north-west boundary of the main gneissic area, passing obliquely across the peninsula, is exceedingly tortuous, the metamorphic rocks being exposed wherever the various overlying deposits, the upper transition

rocks, the lower Vindhyans, the Gondwánas, and the Deccan trap have been removed by denudation. As the nature of the junction with the gneiss will necessarily be described in connection with each of these formations, it need not be repeated here.

The present surface-configuration of the gneiss is very varied, and altogether assignable to denudation. On the Bengal side there is the upland or plateau of Hazáribágh and Chutia Nágpur, much of which has an elevation of 2,000 feet, scattered hills ranging up to 4,000. The high-level gneissic mass beneath the Deccan trap on the Mandla plateau, and extending eastwards to Sirgúja, and westwards through Chindwára and Betúl, may have some structural affinity with the highland of Chutia Nágpur, the general east-north-east and west-south-west strike of the strata being common to both areas.

At a short distance from the coast, between the Máhánadi and the Godávari, the highlands of Jaipur form an independent watershed of gneissic rocks. A basin of Lower Vindhyans bounds this highland on the north-west; on the north-east a broken chain of Gondwána outliers in the Máhánadi valley separate it from the Chutia Nágpur plateau, and the continuous basin of these deposits in the Godávari valley separates it from the Hyderábád plateau on the south-west.

The gneissic plateau of Hyderábád, between the Godávari and the Krishna, has only an elevation of about 1,100 feet. It is in the south of the peninsula that the gneiss attains its greatest prominence, in the plateau of Maisur and the Nilgiris, culminating in the peak of Dodabetta, 8,760 feet high. The Pálghát gap separates the Nilgiris from other lofty clusters of gneissic hills, the Palne and Anámale, in Trávancore.

The main gneissic area is so extensive, and many parts of it are so little known geologically, that it is impossible to give a general description of its characters, and it is better, when noticing the more important peculiarities of the rocks, to treat separately of those portions of the region which have received special notice, and concerning which any details of importance have been recorded. The following are the tracts, included in the main area, of which some information is recorded, beyond the mere occurrence of metamorphic rocks:—

1.—Bengal area.
2.—Singhbhúm.
3.—Orissa.
4.—Central Provinces.
5.—South Máhratta area.
6.—Southern Konkan.
7.—Wainád.
8.—Nilgiri Hills.
9.—Trichinopoli and Arcot.
10.—Assam.

The Bengal area (including Bhágalpur, Birbhúm, Hazáribágh, Chutia Nágpur (Chota Nagpore), Mirzapur, Rewah, and Sirgúja).—

The probability of a difference in age between the gneiss of Bundelkhand and that of Bengal has already been suggested, the suggestions being chiefly founded on the different stratigraphical relations between the gneiss of each area and the Bijáwar formation. In connexion with this question it is fortunate that the best information we possess regarding the characters of the rocks of the main gneissic region refers to the ground contiguous to the Bijáwar basin, in Rewah, Mirzapur, and Behár. There is the further advantage that Mr. Mallet is again our authority, so that we have not to allow for discrepancies of observation.[1] He gives the following tabular abstract of the constituents of the gneiss in Singrauli, a petty principality now absorbed in the Rewah State and adjoining districts:—

1.—Minerals occurring as constituents of the gneiss:—
Quartz; orthoclase; oligoclase; muscovite; biotite; hornblende; epidote.

2.—Occurring in beds in the gneiss:—
Limestone; dolomite; corundum; magnetite; quartz as quartzite and quartz-schist; hornblende as hornblende-rock, tremolite-rock and jade; mica as mica-schist; epidote.

3.—Occurring in veins in the gneiss:—
a.—Quartz in veins and reef-quartz.
b.—In pegmatite veins (as constituents): orthoclase; oligoclase; quartz; mica.
c.—In epidotic veins: epidote; quartz.

4.—Accidental minerals in the gneiss:—
Magnetite; ilmenite; schorl; garnet; stilbite (?).

5.—Accidental minerals occurring in the subordinate beds (2) of the gneiss:—
a.—In the limestone: magnetite; pyrite; hæmatite; serpentine; chrysotile; phlogopite(?); wollastonite.
b.—In corundum bed: schorl; euphyllite; diaspore.
c.—In jade bed (associated with corundum): corundum; rutile (?); schorl; euphyllite.

6.—Accidental minerals occurring in the veins, &c., in the gneiss:—
a.—In the quartz-veins: micaceous iron; tremolite; augite; epidote; schorl; muscovite.
b.—In the quartz-reefs: galena; cerusite.
c.—In the pegmatite veins: schorl; garnet.

To this list may be added the minerals found by Mr. Mallet in the same zone, further to the east, in Hazáribágh: lepidolite; tourmaline; beryl; apatite; leucopyrite; tin stone. Zircon is also said to occur.

The contrast between the minerals named in this table and the constituents of the Bundelkhand gneiss is very striking. The most marked differences are the abundance of the disseminated quartz, the

[1] Mr. Mallet's work has been only partially published: Rec., G. S. I., Vols. V, VI, VII.

comparative frequency of limestone and dolomite and of mica schist, and the general occurrence of accessory minerals in the Bengal gneiss. According to some current theories, by Dr. Sterry Hunt and others, on the chemistry of the primeval earth, this differentiation of the ingredients would be confirmatory of the opinion arrived at from stratigraphical considerations, that the Bengal gneiss, or part of it, is of later date than that of Bundelkhand.

The structural characters present another noteworthy point of contrast between these two gneissic series. In Bundelkhand the rock is generally homogeneous and amorphous, the foliation obscure and constantly in more or less vertical planes, as if due to the causes which produce cleavage. In the Bengal gneiss bordering the Bijáwar basin on the south, the foliation clearly coincides with the original lamination and bedding. These have a general east-north-east strike, corresponding with that of the main rock-boundaries, but the alternating strata fre quently roll about at low angles of dip, or are crushed together confusedly, the foliation constantly agreeing with the lie of the beds.

Quartz-reefs have been described in this gneiss also, but to a very subordinate extent, and their origin as veins is in many cases open to question. A common mode of occurrence of this quartz or quartzite is close to the boundary of the slate and gneiss series, but it does not coincide with their junction, and it is not in any sense a contact-formation, separating sharply distinct types of rock. It occurs in the strike of the foliation and stratification, and may well be an altered quartzite.

There is a rock common in this northern area of the Bengal gneiss, perhaps occurring most typically within the zone mainly occupied by the transition series. It is known as dome-gneiss, from its weathering into great hemispherical or ellipsoidal masses of bare rock, the only divisional planes being concentric layers of exfoliation. The domes are often several hundred feet high, and form a very peculiar object in a landscape. Foliation is always more or less traceable, and in every respect of texture and composition the rock is the same as that of thin bands alternating with schists in the adjoining ground. Both are often porphyritic, the dome-gneiss generally so, containing large ill-formed (rounded) crystals of felspar. There can be no doubt that the peculiar form exhibited by this rock is due to the occurrence of large masses of more homogeneous composition than usual, but the question is how these conditions were produced, whether we must not suppose a partial degree of plasticity to have been attained, and whether the rock is not in a manner intrusive. At the Kálapahár and the Bhiaura hills on the northern fringe of the

Hazáribágh plateau, and the Mandar hill of the Bhágalpur district in the same geological region, there are very typical examples of the dome-gneiss.

The comparative rareness of trap-dykes in the Bengal gneiss is another point of contrast with the Bundelkhand area. In some parts they are pretty frequent, perhaps most so in the vicinity of the basins of Gondwána rocks, and they are often continuous into such basins, their comparatively recent date being thus fully established; but they are by no means generally distributed.

Pegmatite is not uncommon in the gneiss of Singrauli. Mr. Mallet does not consider this formation to be intrusive; as was explained in the case of the pegmatite of Bundelkhand, its composition varies with the rock it traverses. In northern Hazáribágh, however, he describes the extensive occurrence of intrusive pegmatitic granite ramifying in the most intricate manner in veins and dykes of from half an inch to fifty yards wide, through both the gneiss and the transition schists, and maintaining its composition irrespective of the enclosing rock. It is composed, in order of crystallization, of tourmaline, mica, felspar, and quartz; all four being generally present, but their proportions vary greatly. Its texture is also very uneven, the coarsest forms being often found in comparatively narrow dykes. It is in this rock that the mica-mines of Behár are worked. Not unfrequently the pegmatite assumes the curious form known as graphic granite.

The gneiss of the Chutia Nágpur districts, up to the basin of transition rocks in South-West Bengal, is more or less freely interbedded with micaceous hornblendic and silicious schists, and occasional bands of the porphyritic granitoid variety. Patches also occur of less highly metamorphic schists. This division of the Bengal gneiss will again come under notice in connexion with the transition series.

Singhbhum area.—The junction of the Chutia Nágpur (Chota Nagpore) or Bengal gneiss with the transition rocks of Singbhúm (South-West Bengal) is described by Mr. Ball[1] as a great fault. But within this basin of submetamorphic rocks there are extensive inliers of a gneiss, apparently of an older date than that of Chutia Nágpur. It is very uniform and granitoid, and there is a total absence of the thin-bedded gneiss, schists, etc., which abound in the main gneissic area to the north. In contact with this Chutia Nágpur gneiss, the transition strata exhibit a minimum of alteration and disturbance. Mr. Ball describes them at and near Chaibássa as sandstones and mudstones resting immediately on the rough weathered surface of the granitic gneiss. There are local faults along the boundary, but it is certain that the original relation of the two series is like that

[1] Manuscript reports.

between the Bijáwars and the Bundelkhand gneiss, as already described. In the Singbhúm gneiss we again find a remarkable abundance of trap dykes, forming two intersecting systems having north-westerly and north-easterly courses, respectively.

Orissa area.—Further south, in the Tálchír country, the ordinary type of metamorphic rocks again prevails. The following rough classification of them is given by Mr. Blanford:[1]

Gneiss, *a.*—Hard, coarse, and felspathic, becoming sometimes lithologically a perfect granite.

„ *b.*—Soft, foliated, quartzose or micaceous.

„ *c.*—Compact, but sometimes soft, containing garnets, frequently decomposed,

Hornblendic gneiss or schist, soft and foliated.

Quartz-schist or schistose quartz, occurs frequently in bands separated by softer micaceous layers.

The variations in composition coincide with the planes of foliation, the prevailing direction being west-north-west to east-south-east.

Central Provinces.—Higher up the Máhánadi valley in the neighbourhood of Sambalpur, Mr. Ball[2] observed syenitic and protogenic gneiss as common, hornblende-rock and schist as somewhat rare, strong quartzites forming the most peculiar feature in the gneiss; mica-schist, quartz-schist, and shaly slate, and in one instance, near Kátikéla, north-east of Sambalpur, a conglomerate, were found associated with the gneiss. The strike in this region would seem to be very variable—east to west, north to south, north-west to south-east, and north-east to south-west, being all recorded.

On the same latitude, about Nágpur, Mr. Blanford[3] has noticed the general resemblance of the gneissic rocks to those of Bengal. Here, again, there is much irregularity in the strike.

South Mahratta area.—There is little or no information regarding the gneiss in Hyderábád, but for the adjoining South Máhratta country, Mr. Foote has given a sketch of the metamorphic rocks along the south border of the Deccan trap and of the Kaladgi and Bhima basins of transition and lower Vindhyan formations.[4] Massive syenitic and granitic forms of gneiss in great variety are the prevailing rocks, the schists being subordinate. Of the latter there are, in order of abundance, hornblendic, micaceous, chloritic, hæmatitic, and talcose schists. The two types of rock are not indiscriminately blended. The schists occur in definite

[1] Memoirs, G. S. I., Vol. I, p. 39.
[2] Manuscript report.
[3] Memoirs, G. S. I., Vol. ix, p. 301.
[4] Memoirs, G. S. I., Vol. xii.

bands, but their relation to the gneiss has not been clearly made out, or rather no separation into two series has been established. The relation would seem to be one of association rather than separation. The two run in parallel bands of varying width, having a general north-north-westerly direction, which is that of the main Sahyádri watershed. Mr. Foote indicates nine such alternating bands of gneiss and schist between Raichur and the crest of the ghâts. The gneissic bands are more rocky and prominent than those of the schists. They all pass southwards into Maisur (Mysore). The micaceous schists are most developed in the west, where they occur in force underlying the trap of the great scarp.

Crystalline limestone was observed in places associated with the schistose bands of the gneissic series in the South Máhratta country. The chief of these is the massive band of dolomite high on the western face of the Sahyádri range, at the extreme southern limit of the Deccan trap. The fort of Bhímgarh, east of Goa, is built on a mass of this dolomite.

Dykes of a dioritic trap are frequent in these gneissic rocks. Mr. Foote divides them into five groups, according to direction, but remarks that in every case of intersection the rock seemed perfectly confluent, as if both dykes had been simultaneously filled. This trap does not penetrate the overlying transition formations. Small veins of pegmatitic granite are of frequent occurrence in the Southern Máhratta country, but their intrusive origin is somewhat doubtful.

Some strong reefs of quartz occur in different parts of this region. They are mostly of pure white quartz, often in a brecciated condition, and re-cemented by vein-quartz or by some form of hæmatite. Their principal directions are north-west, north-east, and north.

The small auriferous tract of the Dambal or Kappatgudd hills is immediately south of the South Máhratta country, and the rock features described by Mr. Foote are very similar.[1] The gold-bearing reefs occur in a broad band of chloritic, hornblendic, argillaceous, and hæmatitic schists between two strong bands of granitoid gneiss, that on the east seeming to overlie the schists. The north-north-west strike still prevails. The most productive reefs also have this direction. The sources of all the streams said by the natives to be auriferous are within a tract of pseudo-diorite, which Mr. Foote does not consider to be irruptive, but a more developed metamorphic condition of the schists. Trap-dykes occur, but nothing special is noted of them.

Gneiss of the Southern Konkan.—The gneissic rocks of Sáwant-Wári and Ratnágiri, in the Konkan—the low country between the Sahyádri

[1] Records, G. S. I., Vol. vii.

range and the sea—would seem from Mr. Wilkinson's[1] description to be more varied than on the Deccan plateau above the ghâts. The distribution in separate bands of more massive and more schistose characters does not occur. The beds consist of true gneiss (*i. e.*, a well foliated quartzo-felspathic rock), micaceous and hornblendic schists, quartzites and altered micaceous sandstones, with some subordinate bands of granitic and syenitic gneiss, also occasional talcose, chloritic and actinolitic schists; limestone is only noticed near the foot of the Talewari ghât. The structure, too, seems more variable; north of the Tillar river a north-easterly strike prevails. The mass of porphyritic syenite forming Wajhiri hill, 5 miles from Vingorla, is considered to be intrusive.[2]

Gneiss of the Wainad.—Our next note upon these rocks refers to another gold-bearing tract, that of the south-east Wainád (Wynaad), on the uplands of Maisur (Mysore), at the north-west base of the Nilgiris. The position seems to be structurally important. In the little map published with Mr. King's report[3] on this ground the greater part of the area is shown to be within the region of the steady east-north-east strike which obtains in the Nilgiris and along the south-east edge of the Maisur plateau; but towards the north there is an area of troubled dips centred round two masses of granitoid rock forming the Munny Male and Yeddakul Male. Mr. King treats these granitic masses as (doubtfully) intrusive; north of them the foliation again passes into the normal north-north-west strike of the Sahyádri. This Nilgiri strike is noted as distinctly that of the lamination and bedding of the gneiss as well as of the foliation, the general dip here being southerly. Four belts of gneiss are recognised in the south Wainád: the quartzo-hornblendic gneiss of the northern face of the Nilgiris, and below (north of) it the Dayvallah band of highly felspathic gneiss with two minor belts of chloritic gneiss; north of this is the quartzose and ferruginous band forming the Marpanmudi range, beyond which is a broad area of more varied gneiss. The auriferous quartz-reefs are perhaps most developed in the Dayvallah band. Their lie is peculiar; the strike is north-north-west, corresponding with that of the gneiss in the country to the north, and at right angles to that of the rocks in which they occur, yet they generally have a low dip, from 10° to 30°, always easterly. One small trap-dyke occurs in the Dayvallah band; it runs east-by-north, nearly in the strike of the gneiss.

[1] Records, G. S. I., Vol. iv, p. 44.

[2] Some allowance must be made for discrepancies of nomenclature between different observers in these rocks: *e. g.*, some might call an altered micaceous sandstone, what others would name a quartz-schist.

[3] Records, G. S. I., Vol. VIII, p. 29.

Gneiss of the Nilgiris.—In the Nilgiris,[1] massive (obscurely foliated) gneiss prevails, but it is of a very different type from the massive gneiss of the South Máhratta country, which is granitoid and copiously felspathic. On the Nilgiri plateau it is in the very hornblendic variety of the gneiss, such as prevails over the northern portion, that the foliation is least marked. The rock is described as hard, tough, and black, breaking with an even fracture, and consisting of an intimate mixture of quartz and hornblende with some garnets. It was mistaken by early observers for syenite and greenstone. A similar rock, but with a variable proportion of felspar, is very common in the central parts of the hills. There are also several strong courses of a quartzo-felspathic gneiss, which has been taken for graphic granite. Locally this gneiss also contains garnets in great quantity.

A few thin dykes of trap have been observed in the Nilgiri hills, but no granitic veins. Small irregular veins of white quartz are common, but no reefs have been observed.

Gneiss of Trichinopoli and Arcot.—To the south as well as to the north of the Nilgiris, the gneiss of the low ground becomes well foliated and schistose. South of Coimbatur a band of limestone has been observed in the metamorphic rocks. Granitic veins are also common in this neighbourhood; they are especially conspicuous in the hill of Sunkerry Droog, but no intruded granite-mass of large dimensions occurs. Mr. H. F. Blanford, from whom the notes on the Nilgiris are taken, describes[2] a band of granitic rock to the north of Trichinopoli, and points out that this band is possibly a continuation of the very similar rocks of Coimbatur. In Trichinopoli, as to the westward, there is no massive intrusion; but the whole band (about 4 to 6 miles wide) may be considered rather as a network of veins running generally in the planes of foliation of a shattered band of highly foliated hornblendic gneiss, which is frequently twisted and contorted in every direction. The veins consist of a largely crystalline binary granite, mica occurring but rarely. The proportions of quartz and felspar vary greatly, and these ingredients sometimes affect the structure known as graphic granite. Mica is altogether a rare ingredient in the gneiss of this region of the peninsula.

A considerable area of the gneissic rocks of Southern India, from the Cauvery northwards, has been mapped in some detail. The geology has been described by Messrs. King and Foote, and the leading features have been made out, or at least suggested.[3] The belt of granitic intrusion

[1] Memoirs, G. S. I., Vol. I, p. 218. | [2] Memoirs, G. S. I., Vol. IV, p. 30.
[3] Memoirs, G. S. I., Vol. IV, p. 269.

already mentioned, along the north bank of the Cauvery, is on an anticlinal axis. Beds of variable gneiss and schists, with some limestone, dip from it on both sides. To the north they pass under the great mass of rocks forming the several clusters of hills in the Salem district, where, as in the Nilgiris, a syenitoid (*i. e.*, hornblendic) gneiss is very prominent. With it are associated the various magnesian schists from which the magnesite of the "chalk hills" is derived, and also the great beds of magnetite which have made Salem famous as an iron-producing district. These are not lodes, but regularly bedded masses of banded iron-ore and quartz, associated with the gneiss. With the aid of the very conspicuous outcrops formed by this rock, several great features of contortion have been made out, proving the strata to be frequently repeated at the surface.

In South Arcot, to the east of the Salem hill-groups, a considerable area is occupied by rocks having a very granitic aspect, yet showing in many places undoubted stratification, and occurring in great continuous ridges, which apparently form anticlinal and synclinal folds. The rock is composed of quartz and white and pink felspar. It frequently contains blocks, both angular and rounded, of hornblende schist. Altogether, the nature of this rock and its position in the metamorphic series are still open questions.

The distribution of the trap dykes in these metamorphic rocks is markedly peculiar, but it has hitherto received no satisfactory explanation. The dykes are very rare and small in the granitic band of the Cauvery, and also in the granitoid rock of South Arcot; on the other hand, they are extremely abundant in the areas of hornblendic schists and syenitoid gneiss. They mostly run at right angles to the bedding, but occasionally in the same direction with it.

North of Trichinopoli a change takes place in the direction of the strike of the metamorphic foliation analogous to that noticed in the Wainád: the east-north-east direction changes rapidly into north-north-east, parallel to the Coromandel Coast. The regularity of the coast-line is no doubt connected with this fact.

It is interesting to note how the main structural features of the fundamental rocks thus determine the actual configuration of the peninsula. All the fossiliferous deposits, and even the later azoic formations, are but patches on the weather-worn surface of this most ancient gneissic mass.

The Assam gneiss.—From the geographical point of view, Assam and the Shillong plateau could not be affiliated to the peninsula, but ally this would seem to be their proper connexion, since the ıg rocks closely resemble the gneissic and transition formations of Bengal, and differ widely from the rocks of the adjoining

mountains to the north and east. The structural characters bear the same relation: on the edges of the Shillong plateau secondary and tertiary strata lie quite horizontally, while much younger deposits have undergone intense disturbance in the contiguous Himalayan and Burmese regions. The plateau thus forms a wedge-like mass of neutral ground occupying an acute angle between two regions of contortion.

The ground to which these remarks apply is not known to extend beyond the Dhansiri river (Golaghát) to the north-east, though it is likely that the gneissic rocks stretch for some distance at least under the alluvium of Upper Assam. The principal area is the continuous hill-mass, 250 miles long, between the Dhansiri and the Bráhmaputra. It is only the southern border of the hills, where they are capped by the horizontal sandstones, that can be appropriately called a plateau. Even geographically this Assam range is independent, a system of deep longitudinal valleys separating it on the south-east from the Barail ridge, which belongs to the Indo-Burmese mountain system. A single name is much wanted for this well-defined orographical feature; at present it is spoken of in sections corresponding to the tribes who inhabit it—the Garo, Khasia, Jaintea, Míkir, and Nága. The Assam Range would be an appropriate title. The whole of the Lower Assam valley may be included in the same geological region, for the numerous hills protruding through the alluvium north of the Bráhmaputra consist of the same old gneiss, and not of the Himalayan type of metamorphic rocks.

The most interesting of these outcrops in the low ground of the Brámaputra valley is one observed by Mr. Mallet[1] within 200 yards of the tertiary sandstone at the base of the Himalaya on the left hand of the Rydak river, in the Western Bhután Duárs. It is really within the Sub-Himalayan zone, being up a river-valley, inside the mean outer boundary of the sandstones. The rock is thick-bedded hornblende-schist, a common type of rock in the Bengal gneiss, but one that is rare in the Darjeeling gneiss of the adjoining mountains. This is the only instance of close proximity of the azoic rocks of the peninsula to the Himalaya region.

The only observations hitherto made on this Assam gneiss prove little more than that it has a likeness to the Bengal rock, and that the general strike is the same. Some granitic intrusions occur in the transition rocks of the Shillong area, in connection with which they will be noticed.

A few observations on the gneiss of the Arvali region will be given with the description of the transition rocks.

[1] Memoirs, G. S. I., Vol. XI, p. 44.

CHAPTER II.

PENINSULAR AREA.

TRANSITION OR SUB-METAMORPHIC ROCKS, LOWER SERIES.

General remarks — The Bijáwar basin — Bijáwars of Bundelkhand — Gneissoid bottom-beds of the Kén — Dhár forest area — Middle Narbada area — Son-Narbada watershed area — The Son area — The Behár area — Gneissoid bottom-beds of Lakiserai — The Shillong Transition series — South-West Bengal — The Arvali region — Bijáwars of Bágh and Jobat—The Chámpanír area — The Arvali proper — Korana Hills — Malámi beds.

General remarks.—Of the lower transition rocks we can only offer a disconnected and unsatisfactory account similar to that already given of the metamorphic rocks, and for the same reasons—their intrinsic obscurity and the very partial examination they have received. The only difference is, that in the case of the transition series we must make the darkness more apparent by a brief discussion of the leading features of the case; even though this discussion leaves much unsettled, it will serve as a starting-point for fresh inquiry.

The lower transition series, it may be as well to repeat, consists of unfossiliferous schist, quartzite of various kinds, jasper, breccia, limestone, slate, and sandstone which are distinguished from some very similar formations classed as upper transition beds, by exhibiting a greater amount of alteration. Either by metamorphism, conformable sequence, or the intrusion of granitoid plutonic rocks, the lower transition series is connected with the gneiss, whilst the upper transition rocks are distinguished by the absence of any such connection.

The Bijawar basin.—The following remarks refer principally to the great band of sub-metamorphic rocks, stretching in a west-south-west to east-north-east direction obliquely across the peninsula from Bengal to the Narbada valley in Nimár. Geologically we may speak of this belt of transition rocks as the Bijáwar basin, although within the stratigraphical basin the Bijáwar formation is for the most part covered by Vindhyan strata. Owing to this fact, the northern outcrops of the transition series at Bijáwar, in Bundelkhand, are widely separated from their main exposure along the southern edge of the Vindhyan plateau. This principal band of transition rocks is about 700 miles long. There

are many interruptions of continuity by superficial deposits, but the whole forms one structural feature.

A principal doubt regarding the transition rocks of this basin is, whether we have to deal with one formation or with two; whether the rocks of the eastern side, in Behár, are the equivalents of those of the western side, in the Narbada and Upper Son region. The composition of the series is strikingly different in these two positions, and the relations to the gneiss are not uniform. The presumption is perhaps on the whole in favour of the eastern and western series corresponding to each other throughout; but it is well to suggest at once the doubt of the two being identical and to keep it in mind. Our description will begin with the Bijáwar area, then take up the west end of the Narbada ground, and thence work eastwards to Behár.

Bijawars of Bundelkhand.—The commonest bottom-rock of the Bijáwar formation in Bundelkhand is a quartzite. Locally it might be called sandstone. It is generally fine-grained, but sometimes, at the base, coarse and conglomeratic from containing pebbles of white quartz. It rests quite horizontally or with a slight dip upon a denuded surface of the gneiss, even in that most western part of the area, where, as was explained, the uppermost portion of the gneissic series is supposed to be found.

With this quartzite a hornstone-breccia and a limestone are intimately associated. They sometimes replace the quartzite as the bottom rock, or else are interstratified with it, or overlie it. The hornstone is compact quartz, more or less transparent or opaque, of yellow, brown, and red tints; the angular fragments included in it are generally of white quartz, and are always paler than the matrix. In some cases, if not in all, they are clearly the result of fracture; and of fracture not caused by contortion, for the breccia mostly lies quite flatly upon a firm support. Occasionally the former continuity of the detached pieces is evident; the mass looks as if thin bands of quartz had been shattered by concussion, or by shrinkage, then re-cemented in place, and the interstices filled by a more jaspideous form of quartz. The limestone, too, is highly silicious, the quartz appearing both as thin layers and as shapeless irregular segregations of chert.

These bottom rocks of the Bijáwar formation in Bijáwar are very irregular in distribution; in some sections there is no quartzite; in others, no hornstone-breccia, or limestone. The total thickness nowhere exceeds 200 feet. This unevenness of the basement-bed tends to suggest the unconformity of the succeeding deposits, but no confirmation has been

found of this suggestion. On the contrary, sub-schistose shales like those of the upper part of the group are sparingly intercalated with the limestone and quartzite.

More or less earthy ferruginous sandstone, locally somewhat conglomeratic, is the prevailing upper rock, and is associated with rusty shales, incipiently schistose. The iron in these rocks is locally concentrated into a rich hæmatite which has been extensively worked. Several thick but discontinuous beds of dioritic trap occur in the bottom part of the group.

The whole Bijáwar formation in the typical Bijáwar area is probably not more than 800 feet thick. The strata generally either have a very low south-easterly dip, or are quite horizontal; but in a few places to the south, before they become covered up, they are seen to have undergone a considerable amount of crushing, which has not in the least affected the Lower Vindhyan rocks immediately overlying. The general immunity from disturbance in this small area may be due to the original shallowness of the deposits here, where they thinned out over the mass of gneiss, which afforded an unyielding support against compression. It is probable that the transition basin deepens rapidly to the southward beneath the Vindhyan rocks, and that the complete unconformity between the Bijáwars and the Lower Vindhyans, as observed in the Son valley, rapidly replaces the general parallelism of stratification that obtains in the Bijáwar area. East of the Kén (Cane) the transition rocks soon disappear, being totally cut out by the Vindhyans overlapping on to the old gneiss. From a little west of Allahabad all the lower azoic rocks are concealed by the Gangetic alluvium stretching up to the base of the Vindhyan scarp.

Gneissoid bottom-beds of the Ken.—In the east, at Panduah hill and the Kén (Cane) river, a trappean rock occurs below the bottom quartzite, and has received various interpretations from different observers. It was at first[1] grouped with some pseudo-igneous and gneissoid rocks occurring in this section below the normal base of the Bijáwar series. Subsequently by another observer it was classed as a local occurrence of the Bijáwar trap, by a third as the outcrop of a dyke in the gneiss. It is certain that at the Kén the character of the bottom Bijáwar rocks changes rapidly; the strong quartzite thins out suddenly; and a prominent rock on the continuation of its strike is a peculiar sharply cellular quartzite, much quarried for quernstones; but the beds associated with this quartzite are sandstones and shales like those of

[1] Mem., G. S. I., Vol. II, page 37.

the upper part of the series. In the river, and certainly below the horizon of the bottom quartzite of the Bijáwars west of the Kén, there are two or more steady outcrops of pebbly sandstones having the same low south-easterly dip as the adjoining Bijáwar strata, but occurring in the midst of thick pseudo-crystalline gneissic rocks. It is important to notice these observations with a view to their verification or correction, for these sandstones seem to have escaped the notice of the later observers, and they are important as fixing the affinities of the associated gneissic strata with the transition series rather than with the normal gneiss of Bundelkhand. Very similar rocks are found far to the east in an analogous position at the base of the transition series in Behár, and again extensively in the Arvali region; and the whole question is of interest as bearing upon the elucidation of the great gneissic series—as to whether we must not recognise some rocks of this class that are not metamorphic in the full sense of the word, *i. e.*, ordinary sediments transformed, but that are merely granitic or gneissic detritus reconsolidated.

Bijawars, Dhar forest area.—Proceeding from Bijáwar in a south-west direction obliquely across the plateau, where the Vindhyans are for the most part covered by the Deccan trap, we should strike the Narbada about Hindia, at the west end of the wide alluvial plain, 200 miles long, which is in India designated especially as the Narbada Valley. West of Hindia there is a considerable area occupied by transition and gneissic rocks. They abut on the west against the Vindhyan rocks of the Dhár forest[1] area, but appear again in the north of this area and west of it about Barwai. These transition strata have been fully recognised by Mr. Mallet[2] as bottom Bijáwars, consisting of quartzite, hornstone-breccia, and chert-banded limestone identical with those of Bundelkhand. No associated trap rock was observed.

These rocks are more disturbed here than in Bijáwar, but Mr. Mallet describes their relation to the gneiss to be the same, *i. e.*, total unconformity. The quartzite is often found quite flat and surrounded by vertical strata of the metamorphics. It is only possible to question this view by supposing that what we take to be stratification in the metamorphics is a result of molecular forces acting on lines of cleavage. This possibility has been forcibly argued with reference to this very area,[3] and connected with the suggestion that the two series may be very

[1] The Dhár forest is a tract of wild forest-clad hills through which the Narbada flows between Hindia on the east and Barwai on the west.

[2] Unpublished report.

[3] Mem., G. S. I., Vol. VI, pp. 193-202.

closely allied, the gneiss being more or less a metamorphic condition of the Bijáwars.

The possibility and the suggestion are based upon two facts: that the strike of the foliation-planes in the gneiss agrees constantly with the strike of the cleavage-planes in the transition series, and that the chert-bands in the Bijáwar limestones do certainly sometimes occur in the cleavage-planes and not in the bedding. On the other hand, it may be remarked that the lines of disturbance, the synclinal and anticlinal axes, in the Narbada valley, even amongst rocks of much later age than the Bijáwars, observe the same strike as the cleavage and foliation-planes in the old rocks, and that thus at the outcrop the strike of cleavage and bedding would generally agree. As to the chert-bands, they are in any case admittedly of segregative origin, and so cannot be taken as a clue to the arrangement of materials differently aggregated.

Upon the settlement of this question as to the relations between the metamorphic and transition series, it will depend whether the gneiss of the Dhár forest should be affiliated to that of Bundelkhand or to the supposed younger gneiss of Bengal. The composition of the Dhár forest gneiss is in favour of the former relation; and, as there probably is still a broad band of the Bijáwar basin to the southward, the position is not opposed to this view.

Here, as so often elsewhere, a doubt occurs as to the intrusive character of the more granitoid varieties of the gneiss. Some hornblendic and earthy schists of this area, as in the Narbada above Mortaka, where the Indore railway crosses, have been included with the gneiss; but it may be questioned if they do not belong to a transition group older than the Bijáwars.

Middle Narbada area.—Proceeding eastwards up the Narbada valley from Hindia, no rocks are exposed on the northern side, under the Vindhyan scarp, for a distance of 120 miles, to where the Bijáwars form low hills in the Narsingpur district. The cherty limestone and breccia are the only beds seen here; but this may be because the lower rocks are covered by alluvium. The gneiss does not appear again on this side of the valley.

Along the south side of the river, on the edge of the Gondwána formations of the Sátpura hills, there are more frequent outcrops of the transition rocks. The most westerly are near the Moran river, about 30 miles east of Harda, where some narrow ribs of the cherty limestone protrude through the Deccan trap, which from this point covers all the rocks to the west. On this south side of the valley, also, the cherty limestone, generally much contorted and brecciated, is the rock

most frequently seen; but other beds do occur, as in the Bári hill, 15 miles east of Sohágpur, where a considerable thickness of trappoid and earthy rocks is exposed, the latter being so little altered as to be easily mistaken for the Talchir shales of the contiguous Gondwána area. In many places on this south side of the valley, gneissic rocks of doubtful character occur close to the Bijáwars; and the relation between the two series is certainly not simple superposition, both being found at the same level in closely adjoining positions.

Son-Narbada watershed area.—At the head of the Narbada valley in the north of the Jabalpur district there is a continuous exposure of Bijáwar rocks between the Vindhyan and Gondwána areas. We are here on the watershed of the peninsula, between tributaries of the Narbada and the Son. Both these streams have their sources well to the south of the line of their principal valleys, the former flowing from Amarkantak, at the eastern edge of the Deccan trap forming the Mandla plateau; the latter rising not far off, at a slightly lower elevation, in the gneissic rocks that extend to the eastwards from beneath the trappean area.

The space between the Vindhyan and Gondwána basins is very much narrower here than to the west, being only 12 miles wide. The Bijáwars cover the whole ground, but they only form hills 300 to 400 feet above the general level, and no rocks are found very different from those already noticed in the formation. The fact that the beds which we have taken to be the base of the Bijáwars still continue, in the absence of gneiss, to be the prevailing rock exposed along the northern outcrops in the Narbada area, will have suggested that no structural change in the concealed features of the basin has occurred in that position, and that the gneiss probably lies at no great depth; and we learn from the section at the watershed that, here at least, these supposed bottom-beds occur across the whole zone.[1] The section is described as a shallow synclinal; but it scarcely deserves this name, for the bottom, or at least the lowest, rock is as freely exposed in the centre as elsewhere. There must, however, be something of the nature of a basin, as the underlying gneiss only appears along the south margin.

All the leading characters of the formation already noticed are represented here, with a greater development of the argillaceous element. Fine earthy slates of reddish tints are the lowest strata seen; their upper beds are associated with the quartzite which underlies the limestone and is intercalated with it; and the limestone itself is not so constantly cherty as has been described elsewhere. Above the limestone, ribboned jasper beds,

[1] Our notes upon this ground are from unpublished reports by Mr. C. A. Hacket.

passing locally into bluish quartzite, are well developed, and both jasper and quartzite are frequently brecciated. Earthy schists, locally conglomeratic, are also freely associated with this band. The rich iron-ores so largely worked by the natives in this neighbourhood are a concentrated development of the hæmatite and jasper bands of this horizon. Above the iron-band there is again a considerable thickness of earthy schists. Bedded trap occurs throughout the series.

As is implied by the facts already stated, these rocks are not on the whole greatly disturbed. Low undulating dips prevail, although locally there is much contortion. The highly inclined planes, so general in the schists, are of cleavage, not stratification. The thickness of the whole series exposed cannot be great, probably it is under 1,200 feet; and there is scarcely any presumption that the conformable slates beneath the limestone attain any great thickness underground.

Notwithstanding these conditions, the rocks are in an advanced state of metamorphism. The limestone is generally crystalline, the schists are often highly micaceous, hornblendic and garnetiferous, and the iron-ore is mostly the micaceous form of hæmatite. The section in the Narbada at the well known "marble rocks," 10 miles south-west of Jabulpur, exhibits the high degree of alteration and local disturbance to which the Bijáwars have been subjected in this region.

From observations obtainable in this neighbourhood we could only suggest an explanation of these conditions; but from analogy with cases better exposed elsewhere, it is probable that the massive granite, forming such conspicuous rock-features in and near the station of Jabalpur, is of post-Bijáwar age. Here the granite is entirely surrounded by later formations, so that direct evidence of the connexion between it and the Bijáwars cannot be found. The relation of the Bijáwars to the gneiss is better seen. About 7 miles north-east of Jabalpur there is an exposure of true gneiss. Mr. Hacket describes the actual contact of the Bijáwars with this rock, where *upper beds* of the transition series are crushed against the gneiss, and rest upon it, without exhibiting any change or gradation of mineral characters. This is a strong point in the case to be stated presently, as to whether we have to deal with two transition formations in this basin, or with two gneissic series adjoining it.

The Son area.—Immediately to the east of the flat watershed, the band of transition rocks is entirely concealed by an extensive spread of laterite and alluvium, and beyond this we get into the region of the Lower Vindhyans, which stretch to the south of the scarp of the Upper Vindhyan plateau until they nearly come into contact with the Gondwána deposits. After crossing the Son, however, the band of transition rocks

again expands gradually to a width of 25 miles in the south of the Mirzapur district. It is here we encounter the question whether one or two formations occur within this basin of transition rocks.

The northern half (about 10 miles wide) of the transition band, at a little west of the Rehr river, is formed of regular Bijáwar rocks, such as we have hitherto seen them—quartzites, hornstones, banded jasper and hæmatite, limestone and slates or schists, with abundance of intercalated trap. The whole band strikes against and under the Lower Vindhyan strata, where the Son takes a southerly bend opposite Agori. The southern half of the transition band (15 miles wide), as well exposed in the Rehr, is entirely composed of fine slates, with intrusive trap only, the dykes being mostly transverse to the bedding. Both groups are so intensely crushed together that no decisive section of the junction has been found in the low jungle-covered hills. Mr. Mallet mentions an instance at Ubra, at the north end of the section in the Rehr, where a quartzite of the northern set seems to cap a ridge of the slates; but this case is not clear, and the question of the relation is quite open, except that it certainly is not one of horizontal transition, the two contrasting deposits being in full force and character in juxtaposition.

The western extension of the section into the Rewah country has been but imperfectly examined. Already at the Gopat the slates have disappeared, and the northern band of true Bijáwars is in contact with the southern gneiss. In this region, where the Son above Bomársan takes a bend into the area of the transition rocks, there is a good instance of local metamorphism: throughout the whole length between the Gopat and the Son at Murai, the transition rocks along the Lower Vindhyan boundary, distinctly recognisable as Bijáwars, are in a gneissose condition, and granitic intrusive rocks occur in them. The character of the contact of these beds with the main gneiss to the south is, however, of the kind described by Mr. Hacket north of Jabalpur, abrupt rather than transitional; but it is certain that they themselves are locally gneissic, and have been affected by granitic intrusions.

If it were certain that this character of the contact of the ferruginous Bijáwars with the southern gneiss is constant, and has no connection with faulting and crushing, and also that the gneiss of the Rehr and the Gopat are the same, we could at once affirm the distinctness of two transition groups in this ground; for the junction of the slates of the southern band with the main gneiss is perfectly transitional—a gradual alternating passage from the strong gneiss, through gneissose and other crystalline schists, into the fine clay-slate, as is well seen in the section in the Rehr. But while doubts exist upon these two conditions, it must

remain possible that these slates of the Rehr are only a bottom member of the Bijáwar series.

Behar area.—East of the Rehr and the Kanhar several large inliers of gneiss and of granitoid rocks, of more or less intrusive character, occur within the slate area, and at the Koel gneiss is the only rock seen below the Vindhyans. This encroachment of the crystallines upon the zone of the transition rocks is extended in Behár, where gneiss reaches for some miles north of the trunk road west of Gya, quite across the strike of the slates. Several hills isolated on the alluvial plains in this neighbourhood are of thorough granite.

Immediately east of Gya, transition rocks appear again, on the prolongation of those in the Son valley, and having the same strike. They form several groups of hills in East Behár, most of which stand clear of the main gneissic area, being more or less isolated in the alluvial plains. These are the Maher (Muhair), Rájgir, Shaikhpura, Karakpur (Curruckpore), and Ghidaur hills. Those of Mahábar and Bhiaura are on the northern margin of the gneissic upland. The aspect of all these hills at once shows that they must be formed of very different rocks from the Bijáwars of the west, and suggests also that all these Behár rocks belong to one formation. They present, generally on every side, scarped faces formed of massive quartzites, the associated schists or slates appearing obscurely in the valleys. All the peculiar Bijáwar rocks are wanting; there is no limestone, hornstone, jaspideous ironstone, or bedded trap. The only similar rocks in the west are the slates of the Rehr section; and there the quartzites, which form such a prominent part of the transition series of Behár, are absent.

We have a somewhat detailed description of the Mahábar and Bhiaura hills by Mr. Mallet;[1] and the relation of the two rock-series is shown to be very peculiar. The transition series here consists of three divisions: an upper, composed exclusively of strong quartzites, as seen in Mahábar hill; a thick middle band, in which fine mica-schists largely predominate; and a basal member, in which quartzites again occur, sometimes in great force, as when forming the Bhiaura ridge, but at no great distance they may be altogether wanting. This proved inconstancy of the bottom quartzites will (by leaving their presence or absence a character of no importance) make it easier to correlate the group with other rocks; while their frequent presence here is of great service by removing the doubts that so often arise as to whether planes of lamination in schistose rocks of uniform composition are due to bedding or to cleavage.

[1] An abstract of it, without a map, is published in Rec., G. S. I., Vol. VII, page 32.

It would be difficult to draw a more irregularly intricate line than the transition and gneiss boundary on Mr. Mallet's map. Near the Bhiaura and Mahábar ridges there is some approach to an average east-and-west strike of the boundary, but as the plane of junction between the two series rises to the south, its line of outcrop meanders about in the most devious manner. This is not due, as might easily occur, to the irregular denudation of two deposits in flat parallel superposition. Here the lower (older) rock, as a rule, forms the prominences, between which the schists are deeply buried; yet the bedding in both rocks is found to follow the intricate twistings thus produced, the actual junction being generally inclined at a high angle. If the whole surface of contact of the two series could be cleared to view, it would be something like that of the sea in a cyclone.

Even in the absence of the bottom or Bhiaura quartzites, the boundary can always be fixed with precision, on account of the strong contrast between the fine mica-schists and the coarse gneiss; yet the transition rock seems to have fully partaken in the metamorphic action, for it is a thoroughly crystalline garnetiferous mica-schist up to the base of the Mahábar quartzites. Similar variations are found in the gneissic series at the contact: on the north side of the Bhiaura ridge the bottom quartzites lie steeply against the dome-gneiss (p. 20); elsewhere schistose gneiss occurs at the boundary. The dykes and massive outbursts of pegmatitic granite of this region are principally exhibited in the transition series.

A very close connexion is thus established in this position, by conformity of stratification and by a common metamorphism, between the transition rocks of Behár and the gneiss in contact with them; and it is probable that a large part of the gneiss of Bengal is of the same age as that at the boundary of the transition series. There is, for instance, a very distinct outlier of the Mahábar schists and Bhiaura quartzites on the plateau, 30 miles to the south of the boundary in Behár, just north of the Grand Trunk Road at Barhi.

There can scarcely be a doubt that the rocks of the Rájgir and other detached hills of Behár are of the same formation as those of Mahábar, and so the contrast of their mineral condition is interesting. The latter have undergone general crystalline metamorphism, the former have only very locally suffered this change, being for the most part still in an earthy, slaty condition. Yet it would seem that they too are closely surrounded by crystalline rocks; for whenever rock is exposed through the alluvium near these hills, it proves to be granitic. At one spot near Ghansura, on the north side of the Rájgir range, there is a contact showing

distinct intrusion of granite into the soft earthy schists. It is an ordinary ternary granite, not like the pegmatitic granite of the Mahábar region. In the immediate neighbourhood of Gya many forms of special metamorphism and of contact-action are well exhibited. One result of special metamorphism on the earthy ferruginous schists is to convert them into a soft massive trappoid rock, much worked into images and vessels. It would seem even that the conversion had gone the length of producing in this rock the plasticity commonly ascribed to fusion.

The amount of disturbance is rather greater in the detached hills, where the rocks are less metamorphic, than it is in the Mahábar region; and the very peculiar confused form of contortion—noticed above as marked in such detail by the surface of junction where the transition series rises to the south against the main gneiss—is well exhibited throughout the formation, only in larger proportions in the top beds of the series. Mahábar ridge itself is a typical instance of this structure: it is a long, narrow, synclinal ellipse, the quartzites dipping at a high angle all round towards the centre, and curving continuously at each end of the axis. The Rájgir range contains a pair of such ellipses compressed together, the quartzites being for the most part quite vertical along the sides. The Karakpur (Curruckpore) hills, which form the largest of these groups, are a congeries of these discontinuous flexures, little or no regularity being observed in the direction of the axes of contortion. This structural feature as a whole is very puzzling, and apparently inexplicable on the conditions of rigidity which are sometimes considered essential in geological dynamics.

Gneissoid bottom-beds of Lakiserai.—There is still a point to mention in connexion with these transition rocks of Behár. We have seen them in the Mahábar ground resting in apparently regular sequence on the gneiss. The only contacts observed about the Rájgir hills are with intrusive granite; but some distance to the north of this position massive gneiss is exposed in the Barábar hills on the Gya and Patna road. On the east and south of the Karakpur hills the quartzites are in contact with gneiss, but the ground has not been critically examined; on the north a boss of granite appears close to the base of the hills at Urain, south of the loop-line near Kajrah station. We have still to notice the rock underlying the quartzite in the small ridge of Shaikhpura and in the little hills a few miles to the east at Lakisarai (Luckeesarai), the junction station for the chord and loop lines of the East Indian Railway. There can be little doubt that the quartzite of these localities is the bottom-rock of the Behár transition series, the Bhiaura quartzite. In the Shaikpura ridge it rests steeply against a rock having the texture of a thoroughly crystallised coarse

granite, but completely decomposed. The relative position of the two rocks is precisely that of the Bhiaura quartzite and the dome-gneiss. Along a steady outcrop of some 2 miles long no feature of special intrusion was observed, and there is no extra metamorphism at this junction. The only contact-action that occurs is of secondary origin, in the formation of layers and vein-like strings of a sharply cellular quartz-rock much used for making hand-mills.

This section is noticed in connexion with the more decided one at Lakisarai, only a few miles to the east, on the same strike, where the quartzite again rests against an amorphous mass of pseudo-crystalline granitoid rock, but of much less sharply defined texture than at Shaikhpura, and in which strings of pebbles can be detected. This is underlaid by strong beds of coarse conglomerate having the same dip as the overlying quartzite. The pebbles and boulders in this conglomerate are mostly subangular, and are exclusively of varieties of quartzite like those of the overlying formation, none being of crystalline rocks; they often appear elongated in the direction of the foliation, and adhere firmly to the matrix, which is a quartzose, sub-gneissose schist. Just east of Dharárah station some masses of this rock protrude through the alluvium close to the base of the Karakpur hills. Another outcrop of conglomeratic schist was observed under the east end of the Gidhour range and dipping towards it.

These Lakisarai beds remind one forcibly of the pseudo-gneiss observed conformably underlying the Bijáwars in the section of the Kén river in Bundelkhand (page 30), and the suggestion revives, however slightly, the question of the possible correspondence of the transition groups in the two areas.

There is another rock frequently found with the undulating gneissic rocks of Behár and elsewhere in this zone, or protruding from the alluvium near the hills, that suggests the same connection. It is a jaspideous quartzite, often brecciated, and not unlike the bottom Bijáwar rock of Bundelkhand and the Dhár forest. It commonly has the same moderate dip as the rocks with which it occurs; but when vertical or crushed, it is readily mistaken for fault-rock or vein-stone.

If the suggestions here made—of pseudo-gneissic beds occurring locally at the base of the Bijáwars, and related to that formation—should be confirmed, a closer connection might be thought of between the Bijáwars and a portion of the underlying gneiss in Bengal, than is implied by the simple parallelism and transitional metamorphism seen in the Mahábar sections. Suggestions of an opposite tendency can, however, be pointed out from observations recorded in preceding paragraphs: it was stated (p. 35) that the contrasting groups of transition rocks in

the northern and southern portions of the section in South Mirzapur, cannot be in any degree representative of each other by horizontal transition; and the presumption there would be strongly in favour of the southern beds, the slates of the Rehr being the older of the two. If the Behár rocks had to be affiliated to either of these exclusively, it would certainly be with the latter group; and if with the whole series of Mirzapur, the Mahábar quartzites would have to represent the true Bijáwars, which would thus be placed at the top rather than at the bottom of the local transition series. To adjust this point of view, we should have to suppose a break in the Bundelkhand section between the true Bijáwars and the gneissoid beds of the Kén.

The Shillong transition series.—It has been already explained (*supra*, page 26), that the gneissic formations in Lower Assam and the hills to the south are more closely allied to those of the peninsular region of India than to the metamorphic formations of the Himalaya. This relation holds also for the transition rocks, which are largely developed on the south side of the hills, where the sub-metamorphic beds are for the most part covered by the horizontal cretaceous rocks of the plateau, but are exposed in the deep ravines that penetrate to the very axis of the range. The lateral extension of these transition rocks has not been ascertained; on the central cross-section in the Khási country, they stretch for 30 miles from near the south margin of the plateau to beyond the watershed north of Shillong, the culminating ridge with summits 6,450 feet high being formed of the quartzites of the transition series, which rocks have hence been described as the Shillong series.[1]

The position of these Shillong beds is approximately on the continuation of the long tract of transition rocks described as the Bijáwar basin, and the rocks themselves have a general resemblance to those in Behár, at the east end of that tract. They consist of a strong band of quartzites overlying a mass of earthy schists. There also occur intrusively great masses of granite and of basic trap-rock. The former may well represent the similar rock seen to be intrusive into the slaty schists of Rájgir, and for the latter an origin has been assigned similar to that already suggested for certain trappoid rocks in Behár. Thus altogether the affinity is sufficiently marked to introduce the notice of the Shillong area in sequence with that of Behár. In the lofty and deeply eroded ground of the Assam hills the sections are much more favourable for study than on the alluvium-smothered plains country, and some very puzzling observations have been recorded regarding the relations of the hypogene rocks to the Shillong series.

[1] Mem., G. S. I., Vol. VII, page 137.

The lithology of these Shillong rocks varies much according to local conditions of metamorphism. In places the quartzites are quite friable and might be called sandstones; but this state is probably due to partial decomposition, for the intimate texture always reveals the effects of chemical change. Generally the rock is very firm and more or less schistose. It is coarser grained than is common in the Behár quartzites, and at the base, immediately over the slates or schists, there usually occurs a conglomerate, often of considerable thickness, made up chiefly of quartz pebbles, but with some rounded fragments of coloured quartzites. Still, so far as has been made out, the quartzite is conformable to the schists; but in such troubled ground it is difficult to make sure of such a point. The schistose beds also exhibit much variety of texture, from ordinary clay-slate to well-foliated schists and gneiss. These changes are simultaneous in both quartzites and schists, and it is noteworthy that the increase of metamorphism is towards the south, away from the area of the old gneiss.

The relation of the transition rocks to this gneiss has not been made out. On the only section of which we have critical observations, nearly due north-and-south through Shillong, the boundary with the gneiss occurs in the low jungle-covered hills, where observation is almost impossible. The dividing line between the two series crosses the high range to the west of our section, and it is there that the junction should be examined. The observation already noted, that the metamorphism increases to the south, would suggest that the junction of the schists with the main gneiss to the north may be lithologically abrupt. At the southern boundary there is a steep plane of contact between the highly altered transition rocks and the great accumulation of bedded eruptive rock known as the Sylhet trap, supposed to correspond with that of the Rajmahal hills, and therefore to be of Jurassic age. The cretaceous sandstones lie evenly and unconformably on both formations.

In the midst of the transition area there is an extensive exhibition of eruptive rock, of very different character from the Sylhet trap. It is a dense, massive, basic diorite or greenstone. The high road between Surarím and Mauphlong crosses this rock continuously for 5 miles in the gorges of the Kálapáni and Bogapáni rivers. The direction of the road is oblique to the strike of the rocks; but at right angles to its outcrop the greenstone is fully a mile wide. It nowhere betrays any bedded structure, and its intrusive character is not so marked as might be expected with so extensive a display of igneous rock. There is, however, sufficient evidence of intrusion from this greenstone: a well-defined dyke passes from the main mass into

the quartzite of the ridge, about half a mile south of Mauphlong. Elsewhere one may walk for miles along the junction of the two rocks without finding any signs of penetration of one by the other. The general circumstances of this trap have suggested the conjecture that it is in great part the result of the conversion *in situ* of the slates beneath the quartzites.

The relation of the granite, or at least of the larger masses of the crystalline rock, to the transition formation, is also very puzzling. Two such masses adjoin the high road across the Khasia hills. One is the Molím area just south of the Shillong ridge, and close to the road between Mauphlong and Shillong. At Molím this granitic tract is 5 miles wide. Its extension to the east is not known. The other area is much more difficult of approach, the granite being only exposed in the deep gorges under the sandstones of the plateau, as on both sides of Surarím.

The rock is a thorough granite; it commonly affects a spheroidal structure, and it is composed of pale pink orthoclase, often in large crystals, a small proportion of very pale greenish oligoclase, a little dark green or brown mica, and abundance of disseminated hyaline quartz. There can be no question that these great granitic masses are of later origin than the transition series; for the total want of symmetry in the arrangement of the surrounding sedimentary rocks forbids the supposition that they could have been deposited round the granite; yet the same absence of any apparent connection between the form of the intrusive masses and the disturbance of the transition rocks is very difficult to understand. The quartzites (the upper member of the transition series) are generally found at the boundary, but their dip and strike are quite independent of the proximity of the granite, as if their contortions had been fully established before the granite was introduced, and remained quite unaffected by it. The facts seem totally to preclude the notions of fracture and compression commonly associated with the word intrusion. The supposition of the mass being faulted into position also lacks any corroborative evidence; the boundary lines are all rounded, and show no symptoms of fissuring. It is as if a great hole had been burned out of the old stratified rocks and the crystalline mass let in, or as if the transition rocks had been converted into granite up to a certain boundary without affecting the area beyond that line. Yet the facts seem equally against the operation of any agency like molecular transfusion (diagenesis); for the junction is quite sharp, the quartzites not being more altered at the very contact with the granite than away from it. In keeping with all these negative characters is the fact that

no dykes or veins of granite have been observed issuing from these great masses (that of Molím), nor even in their neighbourhood. This is the more remarkable, because dykes and veins of similar granite are not uncommon in the southern part of the area, where the general metamorphism of the transition series is so much greater as to suggest that the focus of hypogene activity lay in that direction, beyond the present limit of these formations, in the ground now occupied by the Sylhet trap. It is also in agreement with the facts and suggestions recorded to note that the granite is younger than the old dioritic Khasia trap: in the bed of the torrent under Surarím, on the east, several small dykes of granite are seen ramifying through the diorite.

South-West Bengal.—The gneissic uplands of Hazáribágh and Chutia Nágpur (Chota Nagpore), about 120 miles wide, separate the transition rocks of Behár from those in South-west Bengal, occupying parts of Mánbhúm (Maunbhoom) and Singbhúm (Singbhoom) districts, and stretching far to the west into the Garhját States, the whole transition area being about 150 miles long from east to west and 80 miles wide.[1]

Although the total thickness of this series must be great, no distinctive zones are marked in it. From top to base it seems to be an indiscriminate alternation of quartzite, quartzite-sandstone, slate and shales, hornblendic, micaceous, talcose, and chloritic schists, the latter passing into potstone; also some bedded trap.

Several large inliers of gneiss occur within this basin of transition rocks. Around some of these inliers, the boundary is quite natural, *i. e.*, in its original condition, as at Chaibássa, where shales and sandstones rest flatly and quite unchanged upon the coarse gneiss of the principal inlier, and the unconformity of the two series is further proved in this case by the fact that the underlying gneiss is profusely traversed by trap-dykes which do not penetrate the surrounding deposits. The boundary between the transition rocks and the main gneiss of Bengal on the north is said to be a fault, on account of the more or less continuous presence along it of a rib of vein-stone. This boundary occurs, however, at the base of a long descending section of the transition rocks, and the beds along the line of junction are such as elsewhere appear as bottom-beds of the transition series. To the east, about Súpur, there are outliers of the slate series beyond the supposed fault-boundary, and at Borobhúm is an inlier of gneiss a short distance inside it. We can at least conclude that the junction here, whether faulted or not, is abrupt, *i. e.*, without any gradation of stratigraphical or mineralogical characters. In this part of the basin, the maximum of

[1] Our few observations on this ground are taken from manuscript reports by Mr. V. Ball.

disturbance and of metamorphism seems to occur away from the boundaries. Further to the west, however, the junction of the slate and gneissic series is described as transitional; and granite veins penetrate the shales without much affecting them.

The most striking feature of this area is a mass of dioritic trap running continuously, nearly east and west, through the centre of the transition basin, but varying in width. Dalma hill, 3,050 feet high, is formed of this rock; and here the outcrop is nearly 3 miles wide. The trap is described as a great dyke, occurring along the axis of a synclinal trough. As the succession of the strata on opposite sides of the synclinal do not correspond, there would seem to be faulting accompanying the fissure. The composition of the dyke is rather peculiar: the axis of the Dalma ridge is formed of a decided breccia, the rock on the flanks being compact or amygdaloidal, with included bands or nests of indurated chloritic schists. The transverse section of it, north of Rámgarh, a little to the west of Dalma, is as follows :—

1. Indurated chloritic schist.
2. Porphyritic trap.
3. Indurated chloritic schist.
4. Compact and amygdaloidal trap.
5. Indurated chloritic schist.
6. Brecciated trap.
7. Indurated chloritic schist.
8. Brecciated trap.

The Arvali region.—The largest area of transition rocks in India is the Arvali (Aravulli) region; but so little is known of it that nothing like a systematic description of the formations is possible. That gneissic rocks largely prevail in the southern and central part of the area, and submetamorphics in the north, has long since been noticed; it is only quite recently that Vindhyan strata have been observed to the west of the Arvali axis. The discovery at the same time of plant-bearing beds, perhaps specific representatives of some Gondwána group, at the base of the Jurassic deposits of Jesalmir, suggests the possible occurrence of outliers of this formation within the area.

The marine Jurassic beds of Western Rájputána form to the westward the natural limit of the Arvali as a geological region. It is, however, a boundary that can only be fixed at a few points, the whole surface being greatly covered by superficial deposits, consisting largely of blown sands. The same difficulty of demarcation is still more felt to the north. The greater part of the Punjab plains is of recent, scarcely pre-historic, origin, all the great rivers being still for the most part occupied in raising their beds; but so far as we know of its underground geology, the whole of this country belongs to the Arvali rock-area. The few small hills on the Chenáb, at Chiniot and Kariána, within 40 miles of the Salt Range, are

of sub-metamorphic rocks, and presumably greatly older than the Silurian or pre-Silurian beds at the base of the section in that range. This is by far the nearest point of approach in North-Western India between the Peninsular and Himalayan formations, to which latter region the Salt Range evidently belongs. Thus the Arvali rock-area, or geological region, has a much wider extension than the geographical feature from which the name is taken.

Bijawars of Bagh and Jobat.—In the extreme south-east of this region, in the Lower Narbada Valley at Bágh and Jobat,[1] the Bijáwar formation has been recognised, specifically identical with the beds in the Dhár forest (*supra*, page 31), the two localities being separated by 80 miles of Deccan trap. This interval, however, is not the principal reason for separating these western localities from the Bijáwar basin: throughout this latter area, for several hundred miles, the strike of the bedding, the cleavage and the foliation in all the rocks, is steady to east-north-east, whereas in the Bágh country the strike in both gneiss and Bijáwars is north-west to south-east. This distinction would, indeed, afford an equally good reason for detaching the Bágh ground from the Arvali region, where the dominant strike is north-east to south-west; but the fact that the underlying crystalline rocks are continuous, must be taken to decide the question: it is in connection with the Arvali area that the affinities of the Bijáwars of Bágh and Jobat would be directly studied.

All the most characteristic rocks of the formation are well represented at Bágh—quartzite, hornstone, breccia, and cherty limestone, and here again interbedded trap occurs, though not found in the Dhár forest area; clay-slate, too, is here more prominent. The town of Bágh stands on the small triangular area of Bijáwars near their south boundary, which is overlapped by cretaceous rocks; the other two boundaries with the gneissic rocks are faulted. The area only extends 7 miles to the north-north-west, and 5 miles to the east of Bágh. The rocks are highly disturbed and cleaved, but the metamorphism is local and moderate.

Jobat is about 16 miles west-north-west of Bágh, and stands at the southern point of another small patch of transition strata. The conditions are peculiar and puzzling. The only recognisable Bijáwar rock is a very typical one, a ferruginous jasper, locally brecciated, with veins of hornstone. It lies almost horizontally, forming a low, scarped plateau. Along the north-east border, south of Anthi, black and grey schistose slates appear between the jasper and the metamorphics, the foliation and apparent bedding in both schists and gneiss being parallel, with a high

[1] Described, Mem., G. S. I., VI, pp. 193 to 202, 303, and 314.

dip to the south-west. Both rocks are highly charged with vein-quartz, suggesting local crushing or faulting. Accepting these beds between the jasper rock and the gneiss as Bijáwars, the similarity in the composition of the transition and gneissic series and their general affinity are considerable: within the transition area, north-west of Saimulda, there are outcrops of talcose and schistose slates and quartzite, with a strong band or vein of coarsely crystallised ternary granite distinctly intercalated in the cleavage-strike (apparent bedding). The schistose slates at the contact of this vein are not more crystalline than usual, and the granite differs from that generally found in the metamorphics. West of Saimulda, close to Andhári, the slates appear to pass along their strike into gneiss and hornblendeschist, becoming more and more crystalline as the metamorphics are approached; but there may be a concealed fault between. Near Jobat, and again 3 miles to the north-west (along the strike), friable calcareo silicious rocks, with seemingly contorted bedding, underlie the horizontal jasper rock.

It is evident that the question here turns upon the point before alluded to (*supra*, p. 31), whether or not the apparent bedding in the schists is real or only induced. In the former case, they can have no connexion with the jasper bed, which would then be the only representative of the Bijáwar formation in this ground. This is, perhaps, the true solution of the difficulty.

The Champanir area.—In the same south-western quarter of the Arvali region there is another basin of transition rocks. It lies between the gneissic upland and the alluvial tracts at the head of the Gulf of Cambay. Here, too, the general strike is west-north-west, nearly at right angles to that of the Arvali range, but the formation lies within the same area of azoic rocks, and so may yet admit of more exact affiliation. The following notice is extracted from the original Memoir on Western India [1]:—

"A small tract, about 30 miles east of Baroda, consists of beds which, although somewhat similar in general character and state of semi-metamorphism to the Bijáwars, differ so greatly in their mineral composition that it appears probable they must belong to a distinct group of rocks. They do not contain any of the rocks so characteristic of the Bijáwars, while their own marked beds are wanting in that series. It is by no means clear whether, if distinct, they are higher or lower in the general sequence; they vary greatly in the extent to which they are metamorphosed, and they are, in the area examined, entirely isolated; very probably they do not differ greatly in age from the Bijáwars.

[1] Mem., G. S. I., Vol. VI, p. 202.

"The area occupied by these beds extends for about 20 miles to the east from Powagarh hill, and for 7 or 8 miles to the south from Chámpanír, at the north-east base of the hill. To the north, they stretch for a considerable distance, but have not been examined. There is also a small tract of hilly country a few miles farther south, which appears to consist of them. As it does not appear at all certain whether they can be referred to any one of the systems of rocks hitherto described as intervening between the metamorphics and the Vindhyans in Central India, it appears best to give them a temporary and local name, and that of the old town of Chámpanír, the former capital of the Mahomedan kingdom of Guzerát, appears best suited for the purpose.

"The principal constituent rock of the Chámpanír beds is quartzite or quartzite-sandstone, very similar in character to rocks which occur both in the Bijáwars and the metamorphics. The other beds are mostly slates, conglomerates, and limestones, ferruginous bands occasionally occurring.[1] Some of the limestones are highly crystalline; in one place near Kadwál they were found to contain actinolite; in other places, as near Surájpur, they were quite unaltered. All the rocks susceptible of cleavage are highly cleaved, the planes striking about west 10°—20° north in general. Some of the slate appears to be so fissile that it might probably be made available for roofing.

"The conglomerates are perhaps the most distinctive beds in the group. They are well seen about Jhaban, on the road between Surájpur and Jambughora. The matrix is in general a coarse, gritty sandstone, containing pebbles and boulders often a foot in diameter, and occasionally more (one was measured which amounted to 3 feet), and consisting of granite, quartzite, talcose slate, and crystalline limestone. The talcose slate of which some of the pebbles are composed is scarcely more metamorphosed than the Chámpanír beds themselves. The quartzite boulders are the largest. The limestone pebbles are very numerous, and as they are dissolved away on the surface by exposure to the weather, the hollows which contained them remain empty, and give a peculiar vesicular appearance to the rock. Some of the limestones of the pebbles contain silicious laminæ, as in the limestones of the Bijáwars, but the rock in this case is more crystalline; it rather resembles the limestone in the metamorphics east of Kanás. The cleavage which is characteristic of the Chámpanír beds throughout, is frequently apparent in these pebbles, though it is but rarely distinguishable in the sandy matrix; none of the pebbles are typically Bijáwar.

[1] Some of these are a rich iron-ore, and occasionally they contain much manganese.

"At one place near Anandpur, the matrix of the conglomerate appears to be a perfect breccia, a mixture of angular fragments of black slaty silicious rock and coarse sandstone, both containing pebbles. This is near the junction of the conglomerate with slaty beds, the latter apparently the newer. The rocks appear to have been much crushed; they look as if angular fragments of slate had become mixed with sandstone, and then all re-consolidated. The granite and quartzite pebbles, however, exhibit no signs of any violence.

"Very little can be ascertained of the sequence of the beds. The slates, limestones, and quartzites of Suräjpur are evidently high in the series; they appear to rest upon the conglomerates of Jhaban, and these again upon the quartzites of Narukot and Dandiapura. Judging from the extent of alteration, too, the Surájpur beds are high in the group; but no base is seen, unless the quartzites of the southern patch rest upon granite about Mankipur. These quartzites much resemble those of Narukot, &c.

"Reference has already been made to the apparent passage of Bijáwars into metamorphics; in the case of the Chámpanír beds, the appearances are much stronger, especially along the southern boundary; so much so, indeed, that it is frequently almost impossible to determine exactly where that boundary should be drawn. Within the tract occupied by the metamorphic rocks, quartzites which have in no way the appearance of outliers, occur in several places, as near Mirwania, and again west of Jambughora. In the latter case, a true conglomerate containing large rolled pebbles of quartzites, &c., and very similar to the conglomerate already described as occurring a little further to the north-west, within the Chámpanír area, is found amongst the metamorphic rocks. The same apparent passage occurs south of Surájpur, the Chámpanír beds being more crystalline near the boundary. There is, of course, the possibility of faults accounting to a great extent for the apparent passages, and when rocks do not differ greatly in mineral composition, apparent cases of transition are very likely to occur; but still there is, in places, an apparent gradual change, both along the line of strike and across it, from Chámpanír beds into metamorphics."

The Arvali proper.—A considerable area of the central Arvalis, north of Abu and Udepur (Oodeypoor), has been cursorily examined; we can at least indicate the main features of the ground and the points that most need elucidation.[1] South of Ajmir, the hills form a continuous range, having a width of about 30 miles, and including summits ranging

[1] The observations on this area are taken from reports by Mr. C. A. Hacket: Records, Vol. X, page 84, and map.

up to 4,200 feet in elevation. The range is composed of a series of ridges with deeply excavated valleys, having a steady strike to north-east-by-north. The watershed occurs in a central depression, from which the streams pass by narrow gorges through the ridges on each side. North of Ajmir, for nearly 100 miles, the continuation of the range consists of narrow and broken ridges of small elevation and separated from each other by several miles of alluvium. Further north, in Shaikhawati (Shekhawuttee), Alwar (Ulwur), and Beána, there are again some considerable groups of hills surrounded by alluvial deposits or blown sand.

It is only in the areas of more or less connected outcrops that there is any chance of working out the succession of the formations. In the central area, south of Ajmir, the lowest rocks, consisting largely of gneiss, are exposed; while in the smaller hills to the north the upper formations are almost exclusively found. This contrast is, to some extent, an effect of surface conditions, for it is plain, from the fringing outcrops of gneiss at the base of the northern hills, that the wide alluvium-covered areas here are for the most part formed of this rock.

In the Alwar hills, the Arvali series has been divided into the following groups:—

Mandan—slates, schists, quartzites.
Ajabgarh—slates, quartzites, breccia, limestone.
Alwar—quartzite, with subordinate bands of schist, conglomerate, and bedded trap.
Schist and limestone (Raiálo).
Quartzite (Raiálo).

The Mandan group is only known in isolated hills, as at Mandan, Tasing, and Barod, 25 miles north-west of Alwar; so that its position, and even its validity as a separate group, are somewhat doubtful. The Ajabgarh group is well exposed about the village of that name in the hills 25 miles south-west of Alwar, where its superposition to the Alwar quartzites is well seen. The Alwar group is by far the most important. It is locally divisible into several unconformable groups, having a great aggregate thickness; so that it is virtually a series rather than a group. In the southern part of the Alwar hills, the Raiálo limestone and quartzite form a doubtfully subordinate or affiliated member beneath the main mass of the Alwar quartzite, which elsewhere rests upon gneiss or passes into it.

The Beána hills (24 miles south-west of Bhartpur), 16 miles long by 10 broad, are formed altogether of the Alwar beds, which are here clearly divisible into five sub-groups, each many hundred feet in thickness, and more or less unconformable to each other; the unconformity being shown either by simple overlap, or by intervening denudation, or by stratification

in oblique contact showing intervening disturbance. The sub-divisions are named after the principal villages of the neighbourhood, as follows, in descending order:—

Weir—quartzites and black slaty shales.
Damdama—quartzites and conglomerate.
Beána—white quartzite and conglomerate.
Badalgarh—quartzite and shale.
Nithahár—quartzite and bedded trap.

It is possible that a very close examination might detect corresponding sub-divisions in the apparently continuous sequence of quartzites in the hills of Lálsot and Alwar. The bedded trap of the Nithahár group corresponds with that at the base of the Alwar quartzites on the south side of the Alwar hills, and it is again found on the same horizon, to the south, in the Rimtumbour hills. The Raiálo beds are not found in the Beána hills.

On the whole, the Arvali transition rocks are strongly metamorphic. The quartzites are commonly sub-vitreous, although sometimes still a free-stone, forming a very fine building material. The limestones are mostly in the condition of crystalline marble; and the schists, even of the Mandan group, often abound in crystals of andalusite, staurotide, and garnet. The conditions of disturbance correspond with those of mineralogical change; high dips and sharp flexures are the rule, flat undulations the exception.

It is in the relation of the Arvali series to other formations that the interest and the difficulty lie. Where first observed in the Alwar hills, the crystalline metamorphic rocks are badly exposed, and the Alwar quartzite seems locally to rest abruptly and unconformably upon a granitic gneiss, whereas elsewhere it passes downwards, by inter-stratification, into a well-foliated gneiss. Had these conflicting relations not been explained, we should have had to distinguish two gneissic formations within the area. From the examination of the Ajmir ground, however, where the base-rocks are exposed, it becomes evident that the supposed granitic gneiss of the Alwar hills is really intrusive granite, younger than the Alwar quartzite. The granite is most abundant along the axis of the range, on a line through Ajmir, Beáwar, and Táràgarh, being generally in the strike of the beds, but also cutting across them into the Alwar quartzites. In the Ajmir hills, there are also numerous sections showing the Alwar quartzite passing down into black gneissose mica-schists with crystalline limestone and schistose quartzites. These would answer approximately to the Raiálo beds of the Alwar hills, and they pass downwards into the gneiss; no separation being discernible. The gneissose Raiálo beds are

the prevailing rock in the Ajmir country, the limestone being very inconstant, even within short distances.

The Ajmir section would agree well enough with those in the Alwar hills, save for some still doubtful cases, where the Raiálo beds seem to be altogether wanting, and the Alwar quartzite is close to gneissic beds of a lower type, thus suggesting here a break in the series, which to the south is unbroken. This discrepancy of the sections at Ajmir and Alwar suggests an explanation of a difficulty that occurs in the Beána hills, about Nithahár, where the bottom band of the Alwar group (the Nithahár quartzites and bedded trap) is found resting on the edges of vertical schists and thin quartzites, no other supporting rocks being exposed in this neighbourhood. It has been stated above how in the Beána hills the several sub-divisions of the Alwar group are more or less unconformable to each other, involving intervening disturbance and considerable denudation, whilst corresponding breaks are only suggested in the Alwar hills by the occasional presence of conglomerate bands. In the Ajmir country, even this evidence of intervals between the groups is not found. It would, however, be a stretch of stratigraphical rules to look upon such total unconformity as that of the Nithahár beds on the schists as a mere local break, and to admit these schists into the Arvali series. According to ordinary practice, these schists would be considered older than the gneiss, with which the same Alwar quartzites are in conformable sequence at no great distance (30 miles). This would, however, be a still more anomalous position to take up; so we are forced to find a horizon for these slaty schists of Nithahár between the trappean zone of the Alwar quartzites and the bottom gneiss. Perhaps, the least forced view to adopt is that they represent the Raiálo beds;[1] in which case these can scarcely be kept in the Arvali series, which would then end (downwards) with the Alwar quartzites. The trappean beds at the base of the Alwar group in the northern hills are not found south of Ajmir.

The relation of the Arvali series to younger formations is also not free from doubt. The boundary of the adjoining Vindhyan basin is for the most part a straight fault-line, running north-east to south-west, parallel with the strike of the older formation; but south-west of Karauli there are some outliers of the Vindhyans resting, with more or less of unconformity, on Ajabgarh beds of the Arvali series. The puzzle occurs in a broken ridge, running close to, and parallel with, the Vindhyan boundary through Hindon, and reaching on the north-east to within 3 miles of the Beána hills. This ridge is mostly formed of well-characterised Gwalior rocks (the ferruginous banded jasper beds), which are placed in our

[1] This is at present Mr. Hacket's view of the case.

upper transition series, as explained elsewhere. Here they are highly disturbed, but not more altered than the Arvalis of the Beána hills. Were these rocks of the Hindon ridge quite isolated, one would scarcely hesitate, from the general conditions of the formations concerned, to place the Gwaliors higher than the Arvalis, the contrast between the composition of the two groups in close proximity forbidding their being identified with each other. But, with the Gwalior jasper beds, there are remnants of a distinct and overlying formation consisting of quartzite sandstone with some red and black slaty shales and irregular bands of limestone. These also are nearly vertical, and roughly parallel to the jasper beds, but certainly unconformable to them. The mechanical relation (parallel unconformity and parity of disturbance) would answer well for that between the Vindhyans and the Gwaliors in the standard area, 70 miles to the south-east across the Vindhyan basin; but these upper beds of the Hindon ridge are much more like to some in the Arvali series than they are to any in the adjoining Vindhyans. In the Alwar conglomerates of the Beána hills, moreover, pebbles have been observed very like the Gwalior jasper. It is agreed, however, for the present to overlook these objections, and to consider these upper beds to be Vindhyan, in view of the more difficult alternative of introducing the whole Arvali series between the Vindhyans and the Gwaliors; and of finding a place for the Gwaliors, as well as for the Nithahár schists, between the Arvalis and the gneiss.[1] The absence of any representative of the Gwaliors between the Vindhyans and the Arvalis in the adjoining ground, south-west of Karauli, is another obstacle to the interpretation proposed.

The many narrow ridges stretching from the south-west into the plains at Delhi and to the west in Hissar, are probably formed of some group or other of the Arvali series. They all have a core of quartzite with more or less vertical bedding, and the associated rocks, as far as they are exposed on the flanks of the ridges, indicate advanced metamorphism. The well-known "flexible sandstone" of Kariána, 60 miles due west of Delhi, occurs in one of these outliers of the Arvalis; it is a locally decomposed condition of a band of gneissose quartzite that is much quarried for quernstones (hand-mills).

Korana hills.—Far to the north-west of the Hissar country, after a wide interval of plains, traversed by the Sutlej and the Rávi, some hills occur on both sides of the Chenáb, at Cheniot and Korána. These hills, to which reference was made a few pages back, are only 40 miles distant from

[1] Mr. Hacket suggests that there may be inversion in the Hindon ridge, whereby the apparently upper rocks (now supposed to be the Vindhyans) may really be the older, and thus presumably Arvalis.

the Salt Range, but the rocks are totally different from any that occur there, and correspond well with the character of the transition rocks of the Arvali series. They consist of strong quartzites, with associated clay slates, forming steep ridges with a north-east to south-west strike. The highest summit is stated by Dr. Fleming to be 957 feet above the plain. The rocks here seem, from the uncertain observations given of them, to be in a less metamorphic state than those nearest them to the south-east—a fact which agrees with their remoteness from what is presumably the centre of disturbance of the region. The oldest rocks of the Salt Range are probably (from their contrasting petrological conditions) very much younger than the strata of Korána; and as the former are at least Silurian, and probably older (the only Silurian fossils being found in a group some distance above the bottom beds) we obtain a small hint upon the age of these transition deposits.

Malani beds.—In the south-west quarter of the Arvali region we may perhaps rank with the lower transition series the peculiar eruptive rocks described as the Maláni beds, as follows[1]:—

It is evident that these, the oldest rocks met with in the portion of the desert traversed, are volcanic. Their extremely silicious nature may be due to alteration, but their porphyritic character, and the occasional occurrence of ash beds, sufficiently attest their volcanic origin. They consist principally of very silicious felsites, so hard that they are not scratched by quartz, and have frequently the appearance and texture of jasper. They vary greatly in colour, from black or dark brown to pink, blue or white, the dark-coloured rock being always hard and undecomposed, whilst the light-coloured varieties are softer and appear to be altered. The most constant character is the presence of small crystals of felspar, usually of a pink or red colour, in addition to which small grains of transparent silica are frequently disseminated throughout the rock.

In places diorite was found associated with these rocks, and in some of the hills west of Bálmir, coarsely crystalline granitoid syenite and pegmatite are intercalated in large masses with the porphyritic felsites. True granite may occur, but in the few hills examined mica was absent, although the character of the rock was distinctly granitic. The presence of similar granitoid rocks elsewhere is rendered probable by the occurrence of pebbles and boulders in some of the later formations.

[1] Records, G. S. I., Vol. X., p. 17, 1877. The portion of the desert traversed was that in the neighbourhood of the road from Umarkot to Jodhpúr *viâ* Bálmir, and from Jodhpúr to Rohri *viâ* Jesalmir. The name Maláni is that of a large district belonging to Jodhpúr; the principal town is Bálmir.

The Maláni rocks must be very ancient, but no idea can be formed of their geological position, as they are nowhere associated with rocks of known age except where underlying beds of comparatively recent date, and nothing resembling them appears hitherto to have been detected elsewhere in India. They form the hills extending upwards of 30 miles west of Bálmir, and south as far as Chotan, 25 miles south-west of Bálmir, and north probably to Vinjorai, 35 miles south-south-east of Jesalmir. South of the Bálmir hills, no rocks are known to occur for a considerable distance, but the syenite hills of Nagar Párkar, which are in this direction, may probably belong to the Maláni series. To the eastward of Bálmir, no rocks are seen for 30 miles, but the prophyritic felsites are extensively developed on the Lúni river for many miles below Jasol and Pánchbhadra; they appear to form a portion at least of the high hills south-west of Jasol, towards Jallor; they constitute the few rocky hills which rise out of the sandy plain between Pánchbhadra and Jodhpúr, and they re-appear at Jodhpúr itself, where some of the beds are unmistakable volcanic ash. On the road from Jodhpúr to Jesalmir, their presence, except near Jodhpúr, was only detected in the neighbourhood of Pokran.

CHAPTER III.

PENINSULAR AREA.

TRANSITION OR SUB-METAMORPHIC ROCKS, UPPER SERIES.

General characters — Gwalior area — Kadapah area — Paupugni group — Cheyair group — Nallamale group — Krishna group — Kaladgi area.

General characters.—It has been already explained that the division of the transition system into an upper and a lower series has been adopted, to a great extent, as a matter of convenience, in order to mark common characters of likeness in some of the many separate rock-basins, and for the purpose of indicating a possible distinction in age between the two divisions. The extremes of the whole series are well marked; on the one side by a close relationship to the adjoining metamorphic rocks, as in Behár, on the other by a total severance from them, as in the Gwalior basin. This character would be an absolute distinction if it were certain that the crystalline rocks were of the same age throughout; but it has been shown that on opposite sides of the Bijáwar basin the same transition beds are in total contrast with the gneiss of Bundelkhand, while they are intimately connected with crystalline rocks in the Son valley. The difficulty in comparing the relations of detached basins of transition strata might be got over if there were any really independent criterion of the relative ages of crystalline metamorphic rocks; but there is no prospect of such a test being available, and to approach a solution by way of detailed work in the field and the laboratory would be an extremely tedious and difficult undertaking. We can thus for the present only suggest a tentative grouping of these rocks, as lower and upper transition: the former, as has already been mentioned, being those that exhibit commonly or frequently an advanced state of disturbance and metamorphism with intimate or doubtful relations to the gneissic rocks; the latter, those that are comparatively little affected by metamorphism, and are quite separate from the contiguous gneiss.

These difficulties and compromises are well illustrated in the Bundelkhand region. On opposite sides of the area, more than 100 miles apart, the Bijáwar and the Gwalior formations rest horizontally or with a gentle slope upon the gneiss, in precisely the same mechanical relation.

The denuded outcrops of the quartz-reefs traversing the gneiss are in both cases covered by the bottom deposits of the overlying transition groups. A slight difference is noticeable at the actual contact; the bottom layer of the Bijáwars is commonly more or less adherent to the gneiss, the result of the partial metamorphism that the Bijáwars, even in Bundelkhand, have undergone; whereas in the Gwalior rocks the purely mechanical texture is still unaffected in the bottom contact-layer. But this difference could count for nothing at so great a distance.

A general list of the rocks of the Gwalior formation would not suggest any separation from the Bijáwars. Each contains sandstone or quartzite, limestone, jasper, and iron bands and bedded traps. The arrangement of these different strata is, however, markedly different in the two cases; and the general facies of these two series does not suggest to the observer that they are representative. Still the Gwaliors are rather more nearly allied by mineral characters to the Bijáwars than to the lower Vindhyans, and on this account the Gwaliors are placed in the intermediate, or transition, rather than in the upper series of azoic formations. The unconformity of the upper Vindhyans upon the Gwaliors is, moreover, of a very marked character: at Ládera (16 miles south-east of Gwalior), Vindhyan sandstone rests upon the gneiss at a lower level than the bottom Gwaliors in the scarp close by.

Three widely separated basins have been classed as upper transition rocks: that of Gwalior in Northern India; that of Kadapah in the North Karnatic region; and that of Kaladgi in the South Mahratta country.

Gwalior area.—The Gwalior area is the smallest of the three, being only 50 miles long, from east to west, and about 15 miles wide.[1] It takes its name from the city of Gwalior, which stands upon it, surrounding the famous fort built upon a scarped outlier of Vindhyan sandstone, which rests on a base of massive bedded trap belonging to the transition period. The composition of the Gwalior formation is very mixed, and admits of only a two-fold and very unequal sub-division. There is constantly at the base a sandstone or semi-quartzite, called the Pár sandstone, from a town 12 miles south-west of Gwalior, a fine-grained stone, pale grey in colour, regularly and thinly bedded. It varies from 20 to 200 feet in thickness, and is overlaid by about 2,000 feet of strata consisting mainly of thin flaggy silicious or ferruginous shales copiously interbanded with hornstone and jasper, both

[1] There is a short notice of the Gwalior formation by Mr. C. A. Hacket, in the Records, Geological Survey of India, Vol. III, page 33. It is also mentioned in Mr. Hacket's paper on the North-East Arvali region: Records, Geological Survey of India, Vol. X, page 84, with a sketch map.

finely bedded and concretionary. The jasper is frequently of a brilliant red colour. Limestone, more or less cherty, occurs on two principal horizons in these shales, but not continuously; and there are two principal zones of a dense basic dioritic trap. All these upper beds, constituting the bulk and the characteristic portion of the Gwalior formation, have been distinguished from the Pár sandstone as the Morár group, the name being taken from the military station close to Gwalior.

With the exception of some very local slips and crushing, the Gwalior rocks are undisturbed, having a steady low northerly inclination of only 3° to 5°. The features of the area correspond with this arrangement of the rocks. There is a continuous broad plateau-range on the south, from 300 to 500 feet high, formed largely of the Pár sandstone. On the west it is connected at right angles with the Vindhyan scarp, which lies at a slightly lower level; and it stretches thence eastwards to the Sindh river, forming a steep scarp to the south overlooking the gneissic area of lower Bundelkhand. There are two other ranges parallel to the Pár scarp on the north, but they are much broken by cross-drainage. The two longitudinal valleys between the three ridges are due to the greater decomposition and erosion along the two outcrops of bedded trap. It is only at the west end, near the Vindhyan plateau, that these trappean bands are well exposed.

With one exception at the west end, where the Paniár stream breaks through to the south, the Pár scarp forms a watershed. The general easterly direction of the scarp is very steady up to the Sindh river, but the line is much serrated by bays and headlands, in which the nature of the junction with the gneiss is well exhibited. At the most advanced points of the range the gneiss reaches to within a few feet of the summit, with only a thin capping of the sandstone, but as we follow the junction northwards into the valleys it gradually falls to the lowest level. A further study of the section shows that this slope of the junction is aboriginal, and not due to a tilt of the ground since the formation of the Gwalior deposits. Close to the edge of the scarp near Pár an outlier of the Morár shale series has been largely worked for iron, and here the Pár sandstone is only about 20 feet thick. Nothing like unconformity has been detected between the Morár and the Pár beds, so that this must be taken as the original thickness of the lower band in this position. On the north side of the range, however, wherever sections are exposed, as about Badháno (10 miles south-east of Morár) the thickness is greatly increased. We may take 200 feet as a minimum, the whole not being seen. In this position, to the east, shales are found intercalated with the sandstone, showing the close connexion of the two groups. These

facts would tend to prove that to some extent the position of the Pár scarp was a limit of deposition in the Gwalior period. The very bottom layer is often conglomeratic.

On the top of the Pár sandstone there occurs locally a compact calcareo-silicious bed that is worth noticing, because the peculiar coralloid forms it exposes by weathering were thought by Dr. Stoliczka to be of organic origin. This rock is best seen just south of Bára, 25 miles east-by-south of Morár.

The lower zone of bedded trap is about 400 feet from the base of the Morár group. There are two or more flows, with intervening shales. They are well seen near the villages of Bela, Chaura, Paniár, and Bárai, on both sides of the Indore road, at from 6 to 10 miles south-west of Gwalior. The thickness of these flows is very various; from 70 feet they thin out to nothing, but are probably nowhere absent on this horizon, obscure outcrops of them having been observed at several places in the valley formed along their strike to the east. At some spots there is an appearance of the trap having burst up through the underlying shales: thus in the stream near the trunk-road north-west of Bela there is a low section showing the shales and trap in vertical contact; but otherwise the interstratification is unbroken.

In connexion with this lower zone of trap there occurs a rock that will again come under notice in these formations and also in the lower Vindhyans. It is a compact porcellanic rock, as sharply and regularly bedded as the associated jaspideous shales. Occasionally it is obscurely porphyritic, having small indeterminate crystals scattered through it. An analysis of a specimen from the Gwalior beds gave the following:—

Silica	60·50
Alumina with a little iron	24·51
Lime	2·08
Magnesia	1·32
Potash	9·16
Soda	4·51

This approaches to the composition of orthoclase felspar. But there is no presumption that this porcellanic rock has any connection with eruptive phenomena, and its association here with trappean beds of highly basic composition, is probably quite fortuitous, for in the lower Vindhyans, where the porcellanic and porphyritoid beds are much more developed, there is no eruptive rock whatever.

The upper zone of trap is on a much larger scale. The whole plain of Morár is underlaid by it, at least on the north side; and if allowance

is made for the small dip, the flow can hardly be less than 500 feet thick. It is admirably exposed in the under-cliff of the Vindhyan scarp in the fort hill and the promontories to the westward. In a small plateau about 3 miles to north-north-east of the fort it is overlaid horizontally by typical, rusty, jaspideous shales of the Gwalior formation. Several detached hills in the plain lying east-by-north of Morár are formed entirely of this massive trap.

Limestone occurs principally on two horizons, in and above the lower trappean zone, and in the northern hills above the great trap-flow. In both positions it is very uncertain and discontinuous. Within a space of 100 yards a mass of limestone more than 50 feet thick is found to be totally replaced by ochreous shales.

The iron ore which is largely mined in the Gwalior formation is quite different from that found in the Bijáwars. The latter is a massive concretionary hæmatite irregularly concentrated in ferruginous earthy sandstones. The Gwalior ore is a fine wafer-like shale composed of thin flakes of hæmatite, with still thinner films of clay. It is a decomposed condition of the jaspideous shales. The amorphous silica has been dissolved out, leaving the iron ingredient in a very favourable state for mining and smelting. The conditions for this change seem only to have obtained near the base of the formation. All the mines are in the shales a few feet over the Pár sandstone.

To the east and north the Gwalior formation is covered by the great alluvial plains; on the west it passes under the upper Vindhyans; and two inliers, exposed by the removal of these covering rocks, are crossed by the trunk-road. The only specific identification of the Gwalior beds beyond this standard area has been already noticed in the concluding portion of the last chapter. The spot is at the nearest point on the opposite side of this northern extension of the Vindhyan basin, 70 miles to the north-west of Gwalior: at Hindon there is a narrow ridge of banded jasper and ferruginous shales which Mr. Hacket considers to be undoubtedly Gwaliors, the conjecture being much supported by the fact that no similar rock, with which they could be confounded, occurs in the Arvali series of neighbouring areas. The Gwaliors at Hindon are more or less vertical; and in contact with them, but not conformably, are some quartzite-sandstone and red and black slaty shales with irregular bands of limestone. By position these beds should be of later origin than the Gwaliors, and on this account Mr. Hacket thinks they must be Vindhyan, although specifically they are in some respects more like rocks of the Arvali series.

The Kadapah area.—The Kadapah formation of upper transition rocks occupies a large area about the middle of the east side of the peninsula, where the coast-line bends from a northerly to a north-easterly direction. This feature has probably a remote connexion with the form of the Kadapah basin, which is roughly of a crescent shape, convex to the west. The north-east horn of the crescent is known as the Palnád, and reaches to Juggiapet, a few miles north of the Krishna river; the southern termination at Tripeti hill is 30 miles north-west of Madras, or only 18 if measured to the outlier at Nagari Nose. The town of Kadapah (Cuddapah) stands in a south-central position near the Pennair river. Gúti (Gooty) is just outside the western border at its centre, and Karnul more to the north, on the Tungabudra, a few miles above the confluence with the Krishna. The length of the basin is about 210 miles and its width 95, the area being nearly 13,500 square miles.

The eastern edge of the basin constitutes a well-defined segment of that vaguely expressed general feature known as the Eastern Ghâts. Locally, the actual face of the highlands is here known as the Yellaconda ridge. It is a flanking member of the Nallamale range, which is formed by a belt of contortion of the Kadapah rocks along this side of their basin. Between the hills and the sea there is a zone of low country, formed of metamorphic rocks and alluvium, about 50 miles wide, constituting the plains of the Karnatic, or Payen Ghât (country below the Ghâts), in the Guntur, Nellore, and North Arcot districts. The elevation of this ground at the base of the hills is under 200 feet, the crest of the Yellaconda rising to about 1,000, and the summits of the Nallamale to 3,500. The centre of the Kadapah basin is occupied by the broad valley of the Khundair, the rocks rising again to form a steep range (locally 2,000 feet above the sea) along the western margin of the basin, overlooking the gneissic upland of Maisur (Mysore) and Bellari, the elevation of which near the range varies from 800 to 1,800 feet according to the position with reference to drainage. The Madras Railway enters the basin at Gúti, and leaves it at the southern point of the crescent, while the Krishna river adopts a very similar course in the northern limb. The watershed of the basin lies far to the north, and the Pennair receives most of the drainage.

More than a third of the area within the boundaries indicated is taken up by the overlying Karnul formation (to be described in the next chapter), which occupies all the low ground of the Khundair valley in the middle of the basin, and another large space in the Palnád. In thickness they are very inferior to the Kadapahs. There

is, no doubt, marked unconformity between the two, but not much more than exists between the several divisions of the Kadapah series, and both have undergone nearly equal disturbance and metamorphism, so that it is rather awkward to draw one of the main divisions of our azoic series between them. It has been already explained that these divisions are to a great extent arbitrary. A difficulty of this kind is always sure to occur in attempting to apply a strict classification over a large area.

The Kadapah formation has been divided into the following groups in descending order[1] :—

Krishna group, 2,000 feet	Quartzites (Srishalum). Slates (Kolumnullah). Quartzites (Irlaconda).
Nallamale group, 3,400 feet . . .	Slates (Cumbum). Quartzites (Byrenconda).
Cheyair group, 10,500 feet	Slates (Pulumpet). Quartzites (Nagari).
Paupugni group, 4,500 feet . . .	Slates (Vaimpulli). Quartzites (Gulcheru).

The distribution of these groups relieves us in some measure of the enormous aggregate thickness of 20,000 feet given in this list. Although in order of time the succession may be taken strictly, it is scarcely to be supposed that there was ever at one spot a continuous superposition of these strata to the extent of their aggregate thickness. The exposed outcrops, at least, do not support such a view; even within the present rock-basin, which must be taken as only a part of the area of deposition, the groups are local and discontinuous, each in turn overlapping the one below it, and resting on the gneiss. In each case, however, there is more or less of denudation-unconformity as well as overlap; so that the groups are much more than mere horizons of variation in deposition.

The original characters of deposition and the induced characters of disturbance are closely related to the actual boundaries of the field. All round the western boundary the junction is natural, *i. e.*, the deposits rest as originally deposited upon the gneiss, the strata having undergone comparatively little disturbance. On the east side of the basin, on the contrary, there has been much contortion of the strata; the boundary is represented as faulted and the beds often inverted, generally presenting the appearance of a band of quartzite dipping steeply towards the gneiss. The lower groups are found to the south-west, and are gradually overlapped to the north and east.

[1] There is a map and description of the Kadapah formation by Mr. King in the Memoirs, G. S. I., Vol. VIII, Part I.

Paupugni group.—In each of the groups of the Kadapah series, sandstones or quartzites prevail at the base, and earthy deposits forming shales or slates above, limestones often occurring with the latter. The Paupugni group is only found between the Tungabudra and the Cheyair, being overlapped in both directions by the Cheyair beds. It takes its name from the river, in the gorge of which the best sections are seen. Its bottom member, the Gulcheru quartzites, rest upon an uneven surface of the gneiss, and rise up to the west to form steep cliffs over an under-cliff of the crystalline rock, as over Gulcheru (15 miles south-south-west of Kadapah). Although the contact is quite sharp, the two rocks are often connected together into an adhering mass. A considerable thickness at the base is coarsely conglomeratic, the pebbles consisting of the brecciated veinstones and banded jasper-rocks which form prominent out-crops in the adjoining metamorphic area. These bottom beds are described as shore-deposits.

In the overlying Vaimpulli sub-division of the Paupugni group, limestone is largely associated with the shales, and intrusive sheets of trap are also of frequent occurrence. In contact with or near the trap, the limestone often contains bands of serpentine and steatite, as may be seen close to Karnul, where the Vaimpulli band has overlapped the bottom sandstones, and rests directly on the gneiss. Vaimpulli is a village 30 miles west-south-west of Kadapah.

Cheyair group—The Cheyair group is well exposed on the Cheyair river. It is divided into two areas by the Karnul formation stretching southwards, west of Kadapah, into contact with the Paupugni rocks. The constitution and relation of the Cheyair group in the two positions are somewhat different. In the north-west area, traversed by the Pennair, the bottom band of sandstones and conglomerates is comparatively unimportant. It is there described as the Pulavaindla sub-division, from a town 40 miles west-by-south of Kadapah. North of the Krishna it overlaps the Vaimpullis, and in the Pennair ground it rests upon their denuded surface, the conglomerates and breccias being largely made up of the characteristic chert-bands of the Vaimpulli limestone. Here, too, intrusive sheets of trap occur in the Pulavaindla band. The corresponding beds in the southern area are described as the Nagari quartzites, from the well-known hill near Madras. They form for the most part in this region the bottom-rock of the Kadapahs, resting on the gneiss. The conglomerates here are made up of pebbles of quartz and quartzites (which are themselves sometimes conglomeratic), and occasionally of red-banded jasper, being thus more like the Gulcheru beds of the Pennair area.

The upper band of the Cheyair group is described in the Pennair area as the Todapurti beds, named from a principal village of the district. They comprise a great series of slaty shales with limestones and eruptive rocks, both intrusive and cotemporaneous, ferruginous chert and jasper beds. The shales predominate; although not greatly disturbed, they are to some extent affected by cleavage, and are hence qualified as slaty. Limestone occurs in two principal bands. It is a finely crystalline grey rock, with much segregated chert, which often assumes very fantastic shapes, especially in the upper part of the beds and near trap-flows. Of these eruptive rocks there are many strong outcrops, in two principal bands, a main one near the base of the group, and another two-thirds up. The only rocks that can be certainly classed as eruptive are coarse-grained, dark, basic diorites, sometimes compact and of grey or pale-green colours. They are shown to be cotemporaneous by their outcrop being continuous for long distances between well-marked bands of aqueous deposits. But frequently the intervening deposits cease, and the flows coalesce; locally, moreover, they are distinctly confluent with intrusive dykes, as is well seen in the small bay below the southern flanks of the Opalpád plateau, 20 miles east of Gúti. Perhaps the strongest argument for the contemporaneity of the bedded traps on this horizon is the fact that no intrusive igneous rock is known to occur higher in the formation, or in the Karnuls, and this could hardly be the case if the massive bands in the Todapurti zone were intruded after the completion of the sedimentary series.

It is in this group, and in the zone with the trap, that representatives occur of the porcellanic beds described in the Gwalior formation. Their presence, as distinctly bedded rocks of quasi-igneous character, and the occurrence of the undoubtedly igneous rocks in a stratified condition, have certainly influenced the argument in favour of the eruptive (volcanic) origin of both. The flaky granulated varieties are taken to be ash-beds, and the compact form is spoken of as felsite. There are, however, great difficulties opposed to the adoption of this view. These highly silicious beds would be of the very opposite type of volcanic products from the real igneous rocks with which they would thus be connected. Silicious lavas are the least prone to assume a finely stratified condition, whereas these beds are quite remarkable for their continuity in thin, sharply defined beds; so that it is very difficult to conceive that they were originally fused rock. It would not be easy to imagine that explosive ejections, alternating with eruptions of basic rock, could be so exclusively of the felspathic type; and it appears probable that any connexion of these porcellanic beds with igneous rocks can only be through the remote and

collateral effects of eruptive action, such as mineral waters. It has been already stated that similar porcellanic beds occur extensively and typically in the lower Vindhyan formation, in which no eruptive rock is found.

In the Cheyair area, the Palumpet slates and limestones represent the Todapurti beds of the Pennair. The traps and porcellanic beds are absent. The limestones are again silicious, and sometimes they are brecciated in a very unaccountable manner, without any disturbance of the strata. Some beds present a rugged humpy surface, suggestive of a coralline formation, but no organic structure has been detected.

Nallamale group.—The Nallamale occupies a larger area than the other groups, principally on the east side of the basin, and takes its name from the mountain range. The Byrenconda summit, 3,500 feet above the sea, gives its name to the bottom band of quartzites. In the Pollconda range, east of Kadapah, these quartzites rest with slight unconformity upon the Cheyair group. In the Pennair area, the strong quartzites of the Gundicotta hills overlying the Todapurti shales are on the same horizon. Here the beds have a gentle north-easterly slope and pass under the Karnul formation, but when they rise again to the east, in the Nallamale, contortion is the rule, often to so extreme a degree as to produce folded flexures and inversion. In the synclinal troughs of these contortions the upper member of the group is found, called the Cumbum slates, the underlying quartzites rising up to form the ridges.

The Cumbum slates are by far the thickest member of the group, and cover the greater part of the area. They are not very uniform in composition. There are several subordinate bands of quartzite, which it is not easy in broken ground to distinguish from the underlying Byrenconda rock, and the slates themselves present many varieties,—from fine, silvery, talcose beds, to coarse, earthy clay-slates of many shades of colour. Occasionally they are foliated and schistose, and not easily distinguished from the schistose beds of the adjoining gneissic area, when the two happen to come in contact; but, as a rule, quartzites are found at the junction. Strong bands of limestone are frequent in the Cumbum slates. The old lead mines near Nundialumpet, 16 miles north of Kadapah, occur in a dark silicious variety of this rock. Generally, it is compact or finely crystalline, micaceous or talcose, of a slate-grey colour with purple tinges.

At the north end of the Nallamale, just south of the Karnul and Guntur road, there is a great dome-shaped mountain known as Eshwaracupum. It is composed of lower Kadapah rocks dipping away from the hill on all sides, and surrounded by Nallamale beds. A

great thickness of strata is exposed, but it is not easy to identify them specifically with the groups already described.

Krishna group.—The fact mentioned, that strong bands of quartzite occur subordinate to the Cumbum slates, introduces much difficulty into the attempt to distinguish a higher group. Thus several ridges within the area of the Nallamale group are thought to belong to an upper independent group. The rock forming the Yellaconda range at the edge of the basin affords an instance. The range is formed to the south of strong, fine, white quartzite, and the Cumbum slates dip under this, whereas on the north the same slates rest upon the quartzites of the ridge which are supposed to be Byrencondas, the ridge itself being continuous throughout. Two solutions have been offered of this puzzle:—that in the southern part of the range the quartzites are inverted, being really the same band throughout; or, that an oblique fault, south-south-east of Gidalur, has brought in an upper quartzite to the south. The fact of the outcrops of such widely different horizons being so continuous, is a great difficulty to this supposition. The question is just mentioned here to indicate the complexities introduced by disturbance in this part of the Kadapah basin.

There seems, however, good reason to suppose that the plateau through which the Krishna has cut its gorge, and which is known as the Krishna Nallamale, is formed of beds higher than the Nallamale group and unconformable to it. These beds are therefore distinguished as the Krishna group. They comprise three well-marked divisions: The Irlaconda quartzities, forming the plateau of that name on the west, where they are 1,200 feet thick; the Shrishallum quartzites, forming a higher plateau to the north and east, called after a well-known shrine on the Krishna; and the intermediate shales, which are called Kolumnullah, after a stream that traverses them. To the north the group spreads out over a flat surface of gneiss, and to the east it passes under the Karnul beds of the Palnád, in which region, again, the rocks on the east are intensely disturbed.

The Kaladgi area.—In the South Máhratta country, on the southern border of the great area occupied by the Deccan trap, and in great part separating the trap-region from the gneissic area of Maisur, there are two basins of somewhat similar formations. This peculiar position is in a manner accidental, for it is certain that the trap once overspread the whole of these basins: along the crest of the Sahyádri it still stretches continuously for some distance to the south of them, and elsewhere outliers of trap are found beyond them resting on the

gneiss. The strata of both basins rest with total unconformity on the crystallines and are quite unaffected by metamorphism. Notwithstanding these similarities of condition, the rocks of the two areas are of different ages, and are considered to be respectively representatives of the Kadapah and Karnul formations, already noticed as occupying a common basin on the east side of the peninsula. In the South Máhratta country the two basins are only 8 miles apart at the Krishna, where the gneiss passes between them and then expands so as to be in contact with the trap for a length of 30 miles. Each basin is more than 100 miles in length, yet no remnant of either formation is found within the limits of the other, so that their separation rests upon collateral petrological evidence, both being totally unfossiliferous. The difference of age between the rocks of the two areas being presumed on the grounds of persistent lithological contrast and the analogy with other deposits elsewhere distinguished by superposition, this isolation in space is strongly suggestive of the supposition that the basins are approximately original, and not remnants of deposits formerly of wide extent. The eastern area is called the Bhima basin, from the large river crossing it centrally; the western is called after the town of Kaladgi on the Gatparba river, and geologically in the centre of the basin, although superficially near its eastern end. The rocks of the Bhima basin are affiliated to those of Karnul, and therefore belong to the lower Vindhyan horizon; while the Kaladgi deposits are ranked with the Kadapah rocks, and so come amongst the upper transition formations of our present provisional grouping.[1]

From the Krishna below its confluence within the Gatparba, the Kaladgi rocks stretch continuously westward for more than 100 miles and then disappear under the trap forming the crest of the Sahyádri. In this direction several inliers are exposed by the local removal of the basaltic covering; the largest, that at the foot of the Phonda Ghât, in the Konkan, is probably continuous with the main basin. On the north there is a large inlier at Jamkhandi. In all of these inliers, however, only the lower beds occur, so it is probable that the formation does not extend far beneath the trap. On the south borders of the basin there are numerous outliers of the bottom quartzites resting on the gneiss, both on the uplands of the Deccan and in the Konkan. The Vingorla rocks and other small islands off the coast all consist of the very hard rocks belonging to the quartzite series. The former continuity of all these patches of rock cannot by

[1] There is an excellent account of the Bhima and Kaladgi rocks in Mr. R. B. Foote's Memoir on the South Máhratta country: Memoirs, G. S. I., Vol. XII, 1876.

any means be asserted, for it is evident that the deposits took place upon a very uneven surface of the crystallines, of which there are extensive inliers within the main basin, as at Gokák.

The total thickness of the Kaladgi rocks is very considerable. They are divisible as follows:—

Upper Kaladgi.

	Thickness.
6. Shales, limestones, and hæmatite-schists . .	2,000
5. Quartzites, local conglomerates, and breccias .	1,200—1,800

Lower Kaladgi.

4. Limestones, clays, and shales . . .	5,000—6,000
3. Sandstones and shales . . .	3,000—5,000
2. Silicious limestones, hornstones, or cherty breccias .	
1. Quartzites, conglomerates, and sandstones . .	

The bottom conglomeratic rocks are made up of the adjoining crystallines, and vary with the composition of the latter. They generally slope up towards the boundary of the area and form a scarp over a basement of gneiss. The cherty breccias form the most peculiar and conspicuous member of this part of the series. Mr. Foote suggests, with much probability, that they are formed by the decomposition and crushing of the highly silicious limestones that occur on the same horizon. A large proportion of the total area, forming a continuous margin to the basin, very wide on the south, and including all the outliers, is formed of the lower members (Nos. 1, 2, 3) of the series, and in this position the rocks are very little disturbed, and scarcely at all altered.

The limestones and shales forming the 4th division of the Kaladgi series are only found in a special basin of depression and contortion on the north-east side of the area. They generally occupy low ground and are much concealed, but may be fairly seen about the town of Kaladgi, exhibiting much disturbance. Several varieties of the rock are very homogeneous in texture and variously tinted, making pretty marble.

The only remnants of the upper Kaladgi group are found in axes of synclinal flexures within this special basin, their preservation being evidently due to their being thus let in and encased by the folding of the whole series. Thus the maximum of disturbance and of metamorphism is exhibited in these remains of the topmost beds of the formation. The principal of these elliptical synclinal areas of the upper groups are those of Anathilli, Shimakeri, Lokapur, and Yenktapur, all within a short distance of Kaladgi. The direction of the axes of disturbance is very steady to between west by north and west-north-west. This is also the direction of the major axis of the basin itself, in which

all the special contortion seems to have been concentrated on the north side, along what is now the lower valley of the Gatparba.

Only four cases of intrusive rock have been observed in the Kaladgi area, and all in the region of disturbance, in the highest beds; three in the Lokapur basin, and one in the Arakeri synclinal valley. They are of compact, green diorite, unlike the older diorites of the gneissic area.

CHAPTER IV.

PENINSULAR.

VINDHYAN SERIES.

General Remarks — Lower Vindhyans, Karnul area — Palnád area — Bhima area — Godávari and Máhánadi areas — Son area — Bundelkhand area. Upper Vindhyans — The Son-Máhánadi boundary — Boundary in Bundelkhand — Boundary on the Ganges — Arvali boundary — Petrology — Relation to lower Vindhyans — Disturbance of the upper Vindhyans — Diamonds — Outliers.

General Remarks.—Vindhyan is one of the oldest names introduced by the Geological Survey. It was originally used to designate the great sandstone formation of Bundelkhand and Malwa, and it was adopted from the name currently applied by Anglo-Indian geographers to the scarped range composed of this formation along the north side of the Narbada valley. The vernacular signification of the term Vindhya is vague, the name being applied generally to the various ranges of hills which divide Hindustan proper, or the Indo-Gangetic plains, from the Deccan, and being quite as often employed for the hills south of the Narbada river, now commonly known to geographers as the Sátpúra, as for the northern range, to which, for the sake of avoiding ambiguity, the name Vindhya is now generally restricted. The Vindhyan formation was thus at first employed as a collective term for the beds in the great rock-basin, stretching in an east and west direction from Sasseram to Nimach (Neemuch), a distance of 600 miles, and from north to south for 300 miles, from Agra to Hoshangabad.

Throughout the greater part of their border, the Vindhyan sandstones are unconformably related to transition or gneissic rocks; but in the eastern branch of the area, in Bundelkhand and the Son valley, they rest with little or no unconformity upon thick deposits of very different character. These lower beds were at first noticed under local names in the several areas, but the convenience and fitness of having a common name for deposits so nearly related was soon felt, and the term lower Vindhyan has been used in this sense.

Lower Vindhyans, Karnul area.—Of the original Vindhyans, now specially distinguishable as upper Vindhyans, no certain equivalents have been recognised south of the Son-Narbada valley, but

of the lower Vindhyans many local representatives are known. Of these the one most closely related to older rocks is the Karnul formation, which lies almost altogether within the basin of the Kadapah upper transition series (see page 60), where it is found in two separate areas; the larger one occupies the whole of the Khundair valley and stretches to beyond the Krishna; the other lies in the district known as the Palnád. The formation here might, without difficulty, be regarded as a member of the Kadapah series: its total thickness is only 1,200 feet, which is less than the smallest group of the Kadapahs; its unconformity to the groups below it is but little greater than these exhibit among themselves; and on the east side of the basin it has undergone the full effects of the disturbing forces which have acted upon the underlying rocks.

The Karnul formation has been divided into the following groups[1]:—

Khundair group .	Shales (Nandiál). Limestones (Koilkuntla).
Páneum group .	Pinnacled quartzites. Plateau quartzites.
Jamalmadgu group .	Shales (Auk). Limestones (Narji).
Bánaganpili group .	Sandstones.

It is principally a limestone formation, with subordinate bands of sandstone and shale. The Bánaganpili sandstone, so called after the town of that name, is usually only from 10 to 20 feet thick, and is sometimes altogether overlapped. There are local signs of its partial denudation below the succeeding limestone, but, on the other hand, some bands of sandstone or quartzite intercalated at the base of this limestone suggest a continuance of the conditions and a close connection of the rocks.

The interest of the Bánaganpili sandstone is, that it is the principal, if not the only, rock of this region in which the diamond is known to be found. Diggings are carried on in many parts of the country on or near the Karnul formation, but mostly in the superficial gravels. At Bánaganpili, however, there have been extensive workings in this bottom sandstone. Shallow pits, not more than 15 feet deep, are sunk in the sandstone, and short galleries driven in the diamond-layer, which must be at the very base of the group or close to the bottom bed. Superficially, the sandstone is hard and compact, and has quite the character of a quartzite; but even at the small depth sunk to, the beds are soft and easily worked.

The Bánaganpili group consists of sandstones, generally coarse, often earthy, occasionally felspathic or ferruginous, and usually of dark shades

[1] Memoirs, G. S. I., Vol. VIII, p. 30.

of red, grey, and brown colours. Pebble-beds are frequent, the pebbles being small and very numerous, composed of quartzite and various coloured cherts, jaspers, and hardened shales, evidently derived from the cherty shales with bands of trappean rock of the Cheyair group of the Kadapah series on which the Bánaganpili beds rest. The diamonds occur in some of the more clayey and pebbly layers. Mr. King records the opinion that they are innate in this rock; but the *gisement* certainly suggests that even in this position they are of detrital origin. It is rather mysterious why the rock-workings should be so crowded as they are over certain spots, whilst large adjoining areas of apparently the very same deposits are left quite untouched. If this irregular distribution of the mines be only due to a delusion of the diamond-seekers, there is still a very large field awaiting exploration.

The Jamalmadgu group takes its name from a large village on the west side of the Khundair valley. It is composed at top of buff, white, and purplish, non-calcareous shales, well seen near the village of Auk (Owk). They have a maximum thickness of 50 feet, and pass down gradually into a finely crystalline or compact limestone, generally blue-grey, sometimes nearly black, and occasionally of pale buff and fawn colours. A very inferior lithographic stone used to be obtained from these beds, but the rock is now much used for building, large quarries having been opened near the railway at the village of Narji, by which name the stone is known. West of Bánaganpili, the Narji limestone is about 400 feet thick, but thins out both to the south and north. In the Raichur Doab, about Karnul, it rests on the metamorphic rocks, where it becomes cherty and brecciated in a peculiar manner, and is there described as a shore-deposit.

Between the open Khundair valley and the western ranges, or Yerramale, there are in the Karnul district some low, flat hills, such as the plateaus of Upalpád and Undútla. These low plateaus are composed of a middle sandstone or quartzite band found locally intercalated in the Karnul limestones and known as the Páneum group, after the town of that name. The greatest thickness of the quartzites is only 100 feet, and the group disappears altogether to the north and south; nor has any sign of it been observed on the eastern edge of the basin. An upper portion formed of firm white sandstone has been distinguished as the 'pinnacled quartzite,' from its mode of weathering; the lower beds, or 'plateau quartzites,' are coarser, more earthy and ferruginous, of various rusty tints.

In a basin of slightly disturbed strata the uppermost group must cover the largest area, and so the Khundair beds occupy the whole valley of

the Khund. There is a thickness of 500 to 600 feet; the upper two-thirds, of purple calcareous shales and earthy limestones, being distinguished as the Nandiál shales, after a large village of that name: they pass insensibly down into purer, compact, and crypto-crystalline, flaggy limestones known as the Koilkuntla band, from a town ten miles south-east of Bánaganpili. The town of Kadapah (Cuddapah) and all the large villages in the centre of the valley are on the Nandiál shales. In this position the rock is soft and crumbling, but to the south and east, on the margin of the mountain region, these uppermost beds of the whole sedimentary basin are quite slaty, being cleaved and contorted proportionally with the underlying formations. In this group also the character of the limestones changes to the north-west, in the proximity of the metamorphics, where the Koilkuntla beds are described as shore-deposits that never extended much beyond their present boundary.

The Palnad area.—The Palnád limestone appears to represent the Karnul formation; and even the sub-divisions have been in a manner specifically recognised in the south-west part of the ground. The limestone is everywhere underlaid by a diamond-bearing sandstone, which has thus been supposed to represent the Bánaganpili rock. In the Palnád country, however, there is great difficulty in distinguishing this rock from a closely associated sandstone clearly belonging to the Kadapahs, but of the Krishna group, at the very top of the Kadapah series and several thousand feet higher stratigraphically than are the beds of the Cheyair group underlying the diamond-sandstone of Bánaganpili. Such at least is the position made out for the bottom sandstone on the south-west of the Palnád towards the expanding rock-basin; on this side, too, some slight unconformity has been pointed out between the Palnád limestone and successive masses of the sandstone, and it has been remarked that the diamond workings here are confined to the rock close under the limestone, so as to suggest the limitation of diamonds to the horizon of the Bánaganpili group. All round the north-east corner of the basin, however, this sandstone, there known as the Jagiapet quartzite, rests directly upon the gneiss.

The leading structural character of the Kadapah basin is maintained in the Palnád: on the west side the strata are comparatively undisturbed, while on the east border they are cleaved, foliated and contorted, and this involves for the Karnul formation a puzzle analogous to that already noticed for the Kadapah rocks (p. 65). According to one interpretation, there would be in the eastern ranges a natural ascending sequence of shales, limestones, and quartzites above what have been described as

the Palnád limestones, and so these upper rocks would be newer members of the Karnul formation; according to another view, this sequence is deceptive, being due to total inversion of the strata, the top quartzite being really a Kadapah rock.

The relation here exhibited shows how arbitrary is the seemingly broad distinction between the upper transition and the Vindhyan series.

The Bhima basin.—On the north-western border of the Kadapah basin, the Karnul deposits are described as overlapping the formations upon which they, for the most part, rest, and as lying upon the gneiss for a short distance up the Krishna valley. Seventy-five miles farther in this north-westerly direction another area is found of rocks having a strong likeness to the Karnul deposits, and resting throughout their entire south-east border, for a distance of more than a hundred miles, immediately upon the gneiss, while along their entire north-western border they are covered by the Deccan trap. The width of the basin thus exposed is exceedingly variable, both boundaries being very irregular in outline. It is greatest, about twenty-five miles, where the Bhima river crosses the outcrop nearly at its middle. From this circumstance the name of the river has been taken for the local designation of the rock-basin.[1]

The Bhima series is mainly a limestone formation, with a total thickness of about 1,000 feet. The following beds have been distinguished in it:—

	Feet.
UPPER.	
(*g*.) Red calcareous shales of Muduwal	30
(*f*.) Flaggy limestone beds of Jewargi	
(*e*.) Buff shales of Gogi	18
(*d*.) Quartzite (sandstone) of Hottapati	200
(c^2.) Blue thick-bedded splintery limestone, brecciated in part	200
(c^1.) Thin-bedded limestone, with chert, of Gogi, &c.	200
(*c*.) Blue and grey splintery limestone, occasionally brecciated, of Shahabad and Talikot	200
LOWER.	
(*b*.) Purple, red, drab, and dark-green shales of Nalwar, with calcareous flags at top	100
(*a*.) Quartzites (sandstones) and conglomerates	60
gneiss.	

It is principally in the south-western part of the area that the bottom sandy beds are developed to any extent. The pebbles of the conglomeratic bands are derived from the adjacent metamorphics, upon a very uneven surface of which the Bhima deposits were laid down, as is shown by

[1] Mr. Foote: Memoirs, G. S. I., Vol. XII.

the very winding outline of the boundary, and by the occurrence of gneissic inliers, some of which are found near the trap of the north-western edge of the area. There is thus no presumption that the sedimentary basin extends far beneath the eruptive rock.

At Bachimali, the extreme easterly point of the southern expansion of the Bhima basin, there is a basement pebble-bed much resembling the diamond-layers of the lower Khrisna valley; it is much broken up by small pits, as if at one time it had been searched for diamonds; but there seems to be no local tradition of any having been found.

The Hottapati sandstone also is quite a local intercalation, so that in some sections the formation is almost exclusively made up of limestone. This is for the most part a very fine-grained rock, with a texture approaching that of lithographic stone. The colours are very various; grey prevails, but drab and pink tints are common. The rock generally occurs in flaggy beds, and is much used for building; the pale cream-coloured variety being preferred by the natives, although the grey stone is the more durable.

The formation has undergone very little disturbance, and the inclination of the strata very rarely exceeds from 2° to 5°. At a few places near the boundary, some crushing and faulting has taken place, as at Gogi, where the lowest beds seen near the gneiss, along an east and west line, are vertical.

There are some patches of a singular limestone-breccia resting on the gneiss within the confines of the Bhima basin, as west and north of the village of Yeddihalli in the Agani valley. The brecciation has clearly been caused *in situ*, and Mr. Foote (*l. c.*, p. 162) conjectures that these patches may be remnants of a former spread of the Kaladgi rocks.

With the exception of a doubtful fragment of silicified wood (or bone) found by Mr. Foote in the basement conglomerate close to the village of Kusukunuhal, just within the Agani valley, no traces of organic remains were obtained from any of the Bhima rocks. Mr. Foote speaks of the limestones as a pelagic formation, and remarks that there is a good deal to suggest that they were once continuous with the like rocks of the Karnul area, and that they have been separated only by denudation.

Mahanadi and Godavari areas.—Between the Karnul and Bhima basins on the south, and the main Vindhyan basin on the north, of which somewhat detailed descriptions have been published, there are numerous areas, some of them very extensive, in the Máhánadi and Godávari river-basins, occupied by rocks belonging either to the lower

Vindhyan or to the upper transition series. These rocks consist of limestones and shales, mostly in low ground, and of quartzite-sandstones, commonly forming ridges and plateaus. They have only received cursory notice in connexion with the adjoining formations, or during rapid preliminary surveys of large areas. Mr. Blanford first noticed them in the country on the Pemganga south-west of Chánda and conjectured their Vindhyan affinities; he considered the sandstone to be the lower member of the series. Coming from the south, Mr. King recognised the quartzites of the Pakhál country north of Kamamet as Kadapahs (they are coloured so on the map accompanying this Manual), and certainly one would *primâ facie* conjecture them to correspond with the bottom sandstones of the Palnád on the Krishna. An observer from the north, familiar with the lower Vindhyans of the Son valley, considered the limestones and shales of the plains of Chhattísgarh to represent that formation. This opinion is now quite general as regards the purple shales and limestones of these several areas, but there is still considerable doubt as to the position of the sandstone or quartzite.

That this doubt should exist implies that the limestones and shales are obscurely connected with the sandstones, or scarcely at all associated. The concomitant opinion that the sandstones are Kadapahs implies that they are apparently the older of the two groups; they are in fact in almost every known section of superposition found to rest upon gneiss, as is nowhere recorded of the limestone and shale group. It has, indeed, been considered by some[1] that the sandstone is the youngest member of the series, apparently for the reason that in contiguous position it occupies the higher ground; this view being reconciled with the fact of the sandstone resting on gneiss, by the supposition of overlap. Elsewhere, however, as along the east border of the Máhánadi basin, the relation has been described as of the sandstone rising from beneath the limestone over an elevated area of gneiss, whether as an original shore-deposit or by subsequent elevation.

It would of course remove the difficulty to suppose that there are two sandstones, but this must not be done without some positive evidence, and Mr. Ball has recently brought some forward from his exploration of the unknown country between the Máhánadi and Godávari.[2] On the upland to the west of the main range of crystalline rocks, the summits of which rise to above 4,000 feet, there is the Nowagarh-Kariál plateau, having an area exceeding 750 square miles, and an elevation of over 3,000 feet, formed of Vindhyan sandstone. Although a plateau, on an

[1] Mr. Hughes: Wardha Valley Coal-Field, Memoirs, G. S. I., Vol. XIII, p. 11.

[2] Records, G. S. I., Vol. X.

upland, it is stratigraphically a basin, the scarp being formed mostly of the top beds resting upon an undercliff of gneiss. In the deeply cut stream-courses, one of which passes right through the plateau, from west to east, a thickness of about 1,500 feet of the sandstone is seen unmistakably resting upon red shales, which greatly resemble those associated with the limestone of the Chhattísgarh and the Pemganga areas. Mr. Ball considers that their identity is probable, and that if so, the Nowagarh sandstone may possibly represent the upper Vindhyans of the great northern basin, for which hitherto no representative has been found south of the Son. These suggestions, however, need confirmation: to show that the Nowagarh sandstone is not the same as that described to rise eastwards from beneath the shales and limestones of Chhattísgarh. It would be passing strange, if this great limestone basin of the upper Máhánadi valley had ever been overlaid by a strong sandstone like that of Nowagarh, that no remnant of this should be left except round the border. The reverse process of denudation is conspicuously the case in the northern Vindhyan basin. It should also be noticed that limestone was not observed with the shales of the Nowagarh basin, whereas it is the most conspicuous rock of the main areas.

The limestones and shales of Chhattísgarh are known to have a great extension, stretching from near Sambalpur for nearly 200 miles westward to the foot of the Mandla plateau. They are believed to occupy the whole of the upper Máhánadi valley, and to stretch across into connection with the like rocks occupying a large area of Bastar, in the upper valley of the Indrawati. The rock-basin would thus have an extent from north to south of about 250 miles, and cover a larger area than the Kadapah basin.

In comparison with this, the ground covered by these rocks in the valley of the Pemganga is insignificant, but there is here the rare occurrence of lower Vindhyan in contact with Gondwána rocks. Along their entire eastern border the limestones and shales of the Pem are overlaid by different groups of the coal-bearing series, or faulted against them. The Pem Vindhyans are covered on the west by the Deccan trap, as are the corresponding deposits on the Bhima.

It was mentioned that the lower Vindhyans of the Karnul and Bhima basins may have been originally continuous, denudation being apparently sufficient to account for their separation. A similar conjecture cannot be so plausibly extended to the limestones and shales of the several basins in the Máhánadi-Godávari area: if the sandstones resting on the gneiss around the borders of those basins belong to an upper group of the series, their overlapping the lower beds would, of course,

debar the supposition. Pending the settlement of this question, we may notice that the disturbance known to have affected these rocks would be enough to account for portions of a once continuous deposit being now completely isolated: the folding and inversion of the Karnul beds along the west flank of the Nallamale (Nullahmullay) in the Kundair valley and the Palnád has been already described; the strata on the east side of the Noagarh plateau were observed by Mr. Ball to be similarly faulted and folded; and a like condition obtains along the north-east border of the Chhattísgarh basin, from Sambalpur to the north-west.

The diamond-washings of the Máhánadi a little above Sambalpur are exclusively from alluvial diggings; but the fact that they occur just outside and below the great lower Vindhyan basin has suggested the conjecture that the gems are derived from those rocks, on the ground that these are the equivalents of the diamond-bearing beds of Southern India. If the conjecture were confirmed, it might be taken as a point in evidence of the equivalence of the formations.

Son area.—There is a much wider and more distinct barrier between the great northern Vindhyan basin and the Chhattísgarh, or upper Máhánadi area, than between the latter and any of the affiliated rocks to the south. The ridge of gneiss which to the west forms the well-raised base of the basaltic plateau throughout the districts of Mandla, Seoni, Chindwára and Betúl, and to the north-east forms the highlands of Chutia Nágpur, is interrupted at this point. It is here that the Gondwána deposits stretch across from the Son to the Hasdu and thence down the Máhánadi valley. The watershed between the Son and the Máhánadi drainage is pretty high, and is occupied by Tálchír rocks, probably of no great thickness: we know, too, that the Vindhyan boundary on both sides runs free of the Gondwána rocks, so it is almost certain that the gneiss must form a rock-barrier from east to west; though of course it is open to question when this may have been produced; it may well be of post-Gondwána age. The junction of the metamorphics with the Vindhyan rocks of the southern area is reported to be abrupt and troubled; but on the north, in the Son valley, observations rather suggest an original limit of the Vindhyans in about the present position; we find the bottom beds constantly at the boundary, and certain coarse deposits on this horizon thicken to the south, presumably to the rise of the original basin.[1]

The map prepared for this Manual is on so small a scale, that one colour has to serve for the whole Vindhyan system; but it is only in the northern basin, where both upper and lower series occur together, that

[1] A description of the Vindhyan rocks of the great northern basin by Mr. F. R. Mallet is published in the Memoirs, G. S. I., Vol. VII.

this might mislead, and it is easy to indicate the narrow limits to which the lower formation is confined. From Sasseram, at the extreme east end of the area, the lower Vindhyans are continuous at the base of the Kaimur scarp for 240 miles; and they disappear at the Son-Narbada watershed, where the upper Vindhyans sweep across into contact with the submetamorphic rocks. The greatest width of the lower Vindhyans across their outcrop in this their typical area is 16 miles, and it is exposed just where the Son enters its main valley from the south. At some points on the lower reaches of the river their outcrop is less than two miles wide. Some small inliers appear through the alluvium in Behar, at a short distance east and north of the termination of the Vindhyan plateau, most, if not all, of them of lower Vindhyan rocks, which also crop out from beneath the upper Vindhyans in some of the valleys on the north side of the plateau west of Sasseram. In this direction, however, the lower Vindhyans soon disappear; and at the lowest level, where the Ganges washes the base of the plateau, at Chunár, only upper Vindhyans are exposed. The concealment of the lower groups is probably only due to depression in the main axis of the basin, for the very same rocks appear again beneath the Kaimur sandstone as it rises towards the gneissic mass of Bundelkhand.

A list of the lower Vindhyans of the Son valley, in approximate order of succession, is as follows (in descending order) :—

11. Limestone.
10. Shales.
9. Limestone.
8. Shales and sandstone.
7. Limestone.
6. Shaly sandstone.
5. Porcellanic shales.
4. Trappoid beds.
3. Porcellanic shales.
2. Limestone.
1. Conglomeratic and calcareous sandstone.

These lithological characters by no means indicate well defined or constant zones in the series; they are all very variable, and pass into each other both vertically and horizontally, by interstratification and admixture of ingredients, and by reciprocal expansion and contraction. The sandstone of No. 8 is steady for 100 miles in the west, forming the conspicuous Kainjua range of hills, and is almost absent to the east, where No. 7 is much more prominent. In the reach between Agori and Bardhi, where the whole formation is most constricted, Nos. 3, 4 and 5 are scarcely represented, and 6, 7; and the sandstone of No. 8 entirely absent. The uppermost beds, Nos. 9, 10, and 11, which collectively might be called the Rotás group, are the most constant of any; and the bottom rocks, Nos. 1 and 2, the most inconstant, which may be explained by their being most affected by the irregularities of the surface on which they were

deposited. All these conditions indicate the unity of the series as a whole. It may have altogether a thickness of 2,000 feet. The petrological resemblance of the lower Vindhyans of the Son valley to those of the southern basins is much less than these latter bear one to another.

The unconformity of the Son lower Vindhyan series upon the transition rocks is total. The bottom conglomeratic beds are often made up of the subangular debris of the Bijáwar jaspideous quartzites, and rest flatly upon the vertically upturned strata of the same. The boundary between the two formations is often straight for considerable lengths, and is otherwise seemingly abrupt, as if faulted; but the local bottom-rock always occurs at the contact; and the numerous and distant Vindhyan outliers, at a slightly greater elevation on the schists to the south, show that the original floor of deposition has not undergone much irregular displacement. Even this rise to the south would seem to be to some extent an original feature; for in these outliers the conglomeratic sandstone, which is the usual bottom-rock, is found in much greater force than elsewhere; it is often very thin, and locally altogether absent at the main boundary, No. 2 or even No. 3 taking its place as bottom-rock: facts which have suggested an original shore of the deposits in this position.

The peculiar pseudo-trappean rocks already noticed in the Gwalior and Kadapah formations are more extensively displayed in the Son area, constituting Nos. 3, 4, and 5 of the list, which attain an aggregate thickness of about 300 feet. The middle beds are the most trap-like; they consist of a rock principally made up of a finely saccharine silicio-felspathic paste, in which innate globular felspar and quartz are unevenly scattered. Where the felspar occurs in nests, it is commonly surrounded by a dark-green, amorphous hornblendic-looking mineral. An analysis (by Mr. Tween) of two samples of these rocks gave the following result:—

	Porcellanic rock.	Trappoid rock.
Soluble in acid	5·5	4·8
Insoluble	94·5	95·2
Silica	86·81	79·35
Alumina	6·25	12·23
Iron sesquioxide (present also as protoxide with a trace of sulphide)	3·10	2·50
Lime	0·12	0·14
Magnesia	trace	trace
Potash	4·10	4·50
Soda	1·00	3·10
	101·38	101·82

The pseudo-trap is particularly well developed in the east about Kon Khás and in the inliers in the alluvium at the mouth of the Son valley. In some of these it rests upon the gneiss, and in such cases it is very difficult to draw a line between the Vindhyans and the metamorphic rocks. The porcellanic beds, as elsewhere, are most regularly and distinctly bedded, and on weathered surfaces they often exhibit minutely fine and continuous lamination. The circumstance that these peculiar beds are most developed east of the Rehr and west of the Gopat, where granitic rocks are abundant in the adjoining areas, suggests the detrital origin of the shales from their crystalline neighbours. The rocks Nos. 1 to 5 of the list may be considered as a lower division of the series in the Son valley.

The porcellanic beds pass gradually up into the shales of No. 6, which, with Nos. 7 and 8, form a middle set of the series on the Son. The shales of No. 6 are easily abraded, and therefore are much concealed. The limestone No. 7 is most developed in the east, where, owing to undulations of the strata, it forms several ridges between the Son and the Kaimur scarp. In the west it is found along the south base of the Kainjua range of hills, formed of the sandstone of No. 8; and this range for a space almost rivals the Kaimur scarp. To the west again the sandstone splits up, and the range comes to an end close to Bijirágugarh.

Some concretionary calcareous shales of No. 8 form a gradual passage into the limestone No. 9, which with 10 and 11 forms the upper division of the series of the Son, more united even than the beds of the middle and lower divisions, for locally the whole thickness is formed of limestone, as at Rotásgarh, the ancient hill-fort at the eastern extremity of the Vindhyan plateau. The limestone is generally distinctly and thinly bedded, and fine in texture, either microcrystalline or compact. It is exceedingly various in composition, sometimes pure, sometimes dolomitic, silicious or earthy. Through the gradual predominance of this latter ingredient it passes both horizontally and vertically into fine flaky silicious shales, No. 10 of the group, which are not confined to any strict horizon, though they occur very generally near or at the top. The thickness of the Rotás group is variously estimated at 700 to 900 feet. It is the most constant member of the lower Vindhyan series in this basin; it appears along the base and in front of the Kaimur range along the whole Son valley from Rotásgarh to where it passes under the upper Vindhyans near Bilheri, a little way to the west of the railway line, and close upon the Son-Narbada watershed. It would thus be more in natural order to speak of the lower Vindhyans becoming uncovered here and gradually more exposed down the valley; the top of

the limestone at Rotás has about the same elevation as the first outcrop near Bilheri at the head of the long valley.

West of the watershed, there is only one small re-appearance of the lower Vindhyans. They disappear at Bilheri under an anticlinal arch of the upper series, which here stretch across to come in contact with the transition rocks along a faulted boundary. In a valley north-east of Kutungi, about 30 miles west-south-west of Bilheri, the top of the anticlinal has been denuded and the lower Vindhyans exposed. For a long way to the west of this no crucial sections are exposed; but where the Vindhyans are next found in original (normal) contact with older rocks in the Dhár forest the lower series is absent. It is also wanting all along the north-west boundary in the Arvali region; and it is equally deficient along the whole western edge of the Bundelkhand gneiss.

Any further description of the stratigraphy of the lower Vindhyans in this basin must be taken up with that of the upper series, which conformably overlies them.

The Bundelkhand area.—It may be considered certain that the Semri rocks under the Kaimur scarp in south-eastern Bundelkhand are the same as the lower Vindhyans of the Son valley, but their appearance on the north is much more irregular in every way—a circumstance which is easily accounted for. From Chebu, close to the Jumna, they are seen at intervals below the Vindhyan scarp for 160 miles, to beyond the Dhasán. The principal exposures are—for 20 miles east of the Dhasán, and for 12 west of the Kén (Cane). East of the latter river the beds are totally concealed for long distances where the upper Vindhyans pass over them on to the gneiss, and the lower formation is only visible in the gorges of the principal streams. About Kirwi, again, where the main scarp begins to trend eastwards, oblique to the general strike of the basin, the lower Vindhyans are freely exposed; but at Bhíta, where the Jumna first touches the rocks of the plateau, a few miles above Allahabad, the upper Vindhyans are at the water-level, the position being more to the dip of the basin.

The rock-groups more or less distinguishable in the lower Vindhyan series of Bundelkhand are as follows (in descending order)[1]:—

5. Limestone (Tirhowan).
4. Shales (Palkoa).
3. Sandstones (Dalchipur).
2. Shales and limestone (Semri).
1. Sandstone (Semri).

Of these, Nos. 4 and 5 very circumstantially represent the Rotás group of the Son—the thin, sharply bedded, fine-grained limestone, of very variable composition both in chemical and mechanical ingredients, and the flaky silicious shales between which, more capriciously than in

[1] Memoirs, G. S. I., Vol. II.

the Son area, the most complete transitions occur vertically and horizontally. When the Bundelkhand ground was first described, the equivalence of these different rocks was not detected, and consequently it was supposed that the shales had suffered denudation before the deposition of the limestone, and the limestone again before the deposition of the Kaimur sandstone (upper Vindhyan), which is found resting directly on both. In one form or the other, as shale or limestone, this group is found from end to end of the outcrop, being, like the Rotás group, the only constant member of the series.

There is one character connected with this limestone in Bundelkhand that does not occur in the Son region: it is almost constantly overlaid by a silicious breccia, not a detrital rock nor a contortion-breccia, but apparently composed of thin layers of agate, chert and jasper, shattered in place either by concussion or desiccation, and re-cemented by sintery or hyaline silica, free from sand or other detrital matter. This breccia is rather connected with the limestone than with the overlying Kaimur sandstone, which often has at its base a breccia-conglomerate very different, however, in character from the Tirhowan breccia, which is adherent to the limestone, and also fills cracks in its upper surface. This bed is sometimes 40 feet thick, as on Panwári hill, south-east of Tirhowan.

Some black concretionary shales in No. 2 may be supposed to represent the exactly similar beds in No. 8 of the series in the Son valley. In both localities explorations for coal have been made in these beds by sanguine adventurers. No further similarities can be traced between the two series: the lower groups in Bundelkhand are even more inconstant than those of the Son.

The greater irregularity of the groups at the outcrop in Bundelkhand is manifestly due to this being the original edge of the deposits. In the Son the neighbourhood of an original boundary not far to the south is suggested, but in Bundelkhand the whole feature is fully exposed. In the gorge where the Semri undercuts the section from north to south, the Semri sandstone does not follow up the rise of the Bijáwar rocks in parallel bedding, but is banked against it in lenticular masses. At the head of the lateral valley to the west, under Chopra, the Semri shales are seen to stretch up against this bank of sandstone with a gradually diminishing thickness, and are in turn cut off by an overlapping sandstone, representing the Dalchipur rock of the Dhasán area, which is itself covered and overlapped by the Kaimur (upper Vindhyan) sandstone, the Tirhowan limestone being altogether cut out, but it occurs in force at the base of the scarp along the principal valley a short distance to the south.

Each of the groups in turn, except perhaps No. 2, is found at or very near to the base of the series. In the west, at the Dhasán and east

of it, the Dalchipur band is the dominant or even the only member present. Near the east bank of the river there is a remnant, about 10 feet thick, of the Semri sandstone, but on the west, under Kurat, the thick pebbly Dalchipur rock lies close upon the Bijáwar greenstone; and to the south nothing is seen between the Dalchipur sandstone and the Kaimur conglomerate. However similar these two conglomerates may be in general characters, they have one striking distinction—the pebbles in the Dalchipur rock are all of white quartz, while those of the upper Vindhyan rocks are almost entirely of red jasper, just like the Gwalior stone. This contrast in itself suggests a great change in the conditions of formation; it may even be a hint that the Gwaliors and lower Vindhyans are nearer to each other in age than our classification would indicate.

In the middle area, at and west of the Kén, the Semri sandstone and the overlying shale and limestone band are well developed. The latter is also fairly seen in the gorges of the Ranj and the Boghin, east of Panna; but in the eastern area, about Kirwi, the Tirhowan (Rotás) limestone, very free from its familiar shales, is with one exception the only member of the series. The exception consists in a very peculiar bottom-rock covering the granitoid gneiss. Where found under the limestone this rock might readily be referred to the Tirhowan group, for it often has layers of dense, fine limestone just like that rock, and it is otherwise cherty, as is often the case with the limestone; but it is largely a detrital rock composed of quartz-sand, felspar-grains, and (characteristically) glauconite. Cherty segregation in many forms—spongy, pisolitic, amygdaloidal or disseminated—gives its most peculiar aspect to the bed. This rock is traceable in the hills south-west of Kirwi, the most north-westerly of which, about Akbarpur, are altogether of metamorphic rock and have a pointed or rounded outline; the next have only a thin cap of Kaimur sandstone; but the sedimentary beds thicken steadily to the south-east, and at the sacred hill of Chattarkot the gneiss appears only at the base on the north-west side. At the high elevation of the junction there is only a remnant of the cherty contact-rock coating the gneiss under the Kaimur sandstone, and in Chattarkot hill the contact-rock occurs under the limestone, holding its position as a true bottom-rock. At a few places in the eastern area the flaggy sandstones of this band are well marked, as in the gullies to the south-east of Chattarkot hill; and they become more developed to the west, as north of Panna on Bisrámganj Ghát, where they are 50 feet thick. In this way they are traceable into relation with the Semri sandstone, in which also glauconite-grains are of common occurrence.

This peculiar contact-rock of the east has been more specially noticed because of a conjecture that it may possibly be an original *nidus* of the

diamond. A common form of it is a semi-vitreous sandstone, or pseudo-quartzite, of a greenish tinge, the result of the local solidification of the sandstone by diffused silica. Large pebbles of this rock are very abundant in the conglomeratic diamond-bed of the Rewah shales at the Panna mines, and it is said they are broken up in the search for diamonds. The diamond-bearing beds of the upper Vindhyans are now at a much higher level than any existing outcrop of the Semri beds; but it is very probable that this peculiar rock once extended over the then elevated surface of the gneissic area. It is, of course, only in view of the remarkable steadiness of the actual horizon of the Kaimur conglomerate and its overlap on to the gneiss, as described in Bundelkhand, that any suggestion need be offered as to how debris of *infra*-Kaimur beds can have found their way into *supra*-Kaimur deposits.

Upper Vindhyans.—The upper Vindhyan formation[1] ranks third in superficial extent within the rock-area of the peninsula, occupying in a single basin a larger surface than the combined areas of any other formation except the gneiss and the Deccan trap. The form of the basin is peculiar: there is a great area, 250 miles long, between Chittorgarh on the west and Saugor on the east, and 225 miles broad from Indargarh on the north to Barwai (or Mortaka) on the south, all presumably occupied by upper Vindhyans, although a very large part of it is covered by the trap of the Malwa plateau. From Saugor a long arm, with a maximum width of 50 miles, stretches eastwards for 340 miles to Sasseram in Behar. Another broader tract extends northwards from Saugor, and passes under the Gangetic alluvium between Agra and Gwalior. The gneissic mass of Bundelkhand lies between these prolongations. The exposed surface of the upper Vindhyan deposits is about 40,000 square miles; and with the area beneath the trap the basin would occupy about 65,000. The classification of the strata composing the upper Vindhyans is as follows:—

BHÁNRER (*Bundair*)	Upper	13. Sandstone.
	Lower	12. Shales (Sirbu).
		11. Sandstone.
		10. Limestone.
		9. Shales (Ganurgarh).
REWAH	Upper	8. Sandstone.
	Lower	7. Shales (Jhiri).
		6. Sandstone.
		5. Shales (Panna).
KAIMUR (*Kymore*)	Upper	4. Sandstone.
		3. Conglomerate.
	Lower	2. Shales (Bijigarh).
		1. Sandstone.

[1] Memoirs, G. S. I., Vol. VII.

The upper division of the Vindhyan system is in the main a sandstone formation, with distinct bands of shales, mostly coarse and flaggy. The only limestone is a subordinate band occurring pretty constantly throughout the area in the Bhánrer group, but the lower Rewah shales (Panna) are locally calcareous. Both the chief and minor sub-divisions are wonderfully persistent over the whole of the great basin, all being found in both the eastern and northern areas into which the main area is divided by the Deccan trap. The lower Bhánrer and lower Rewah sandstones are very attenuated in certain directions, but there is an equivalent increase in the thickness of the enclosing shales. In certain positions also the great bands of shales thin out altogether, and the main sandstones coalesce. These reciprocal variations in the distribution of the coarser and finer deposits have distinct relation to position with reference to the border of the area, the shales being in force towards the middle of the basin, and being replaced by sandstones near the margin, showing that this border is approximately an original limit, and that the actual basin corresponds pretty closely with the basin of deposition. There are local exceptions to this condition, and it is in the direction in which these exceptions occur, *viz.*, on the Arvali side, that the only recognisable distant outliers of the upper Vindhyans have been observed.

A formation so constituted, and for the most part but little affected by disturbance, can result in but one form of surface; accordingly the upper Vindhyan area presents a three-fold plateau, each step formed of one of the main groups, with minor plateaus, terraces or ledges corresponding to the various sub-divisions. The thick sandstones form vertical scarps over a talus of the underlying shales. There is, moreover, a basin-shaped lie of the beds, apparently to a great extent original, whereby the surfaces are rendered more or less concave, and the edges of the successive scarps of sandstone scarcely higher than the outer one composed of the Kaimur rock. From this arrangement it follows that the upper group occupies by far the larger part of the area: even the middle step of the plateau, the edge of which is determined by the Rewah sandstone, is chiefly occupied by the lower Bhánrer shales.

The Son-Narbada boundary.—The lower Kaimur beds are the least exposed of any, and are only known in the eastern arm of the basin, and very locally in Bundelkhand. They are best seen in the gorge of the Ghágar north-east of Agori, under Bijigarh fort, where the shales are 150 feet thick, and the lower sandstone 200 feet. These shales are quite black, and were explored for coal in 1837; but no trace of any such mineral has ever been found in them, or in any part of the Vindhyan series. For some distance to east and west the outcrop of these shales

produces a double scarp on the face of the Kaimur range; but at the extreme eastern end at Rotás the shales are scarcely, if at all, represented, the sandstones forming an unbroken mass.

At this end of the basin the whole Kaimur group is estimated as 1,300 feet thick. In going westward up the Son valley it gradually decreases, disappearing altogether at the watershed, where the Rewah sandstone rests upon the lower Vindhyans, the whole of the lower Rewahs having also vanished. This actual diminution of the Kaimurs and the lower Rewahs westward, along the southern outcrop of the basin, is in reality only due to the thinning out of the deposits southwards, presumably to the rise of the basin, and to their overlap by later beds of the series; for, in passing westwards from Rotás along the northern outcrop, the Kaimur beds continue in force throughout the whole border up to Gwalior; and at the gorge of the Kén, which is about opposite to the head of the Son valley, the group is manifestly thickening to the south, some fine greenish shales appearing at the deepest points of the sections under the Kaimur conglomerate. The group is also well represented along the western border in Rájputána.

At the Son-Narbada watershed, where the Kaimurs are overlapped, the other groups of the formation have been estimated (at Kuttangi) as follows:—

Upper Bhánrers	650
Lower "	1,450
Upper Rewahs	1,000
	3,100

The great thickness of upper Rewah sandstone here suggests that the disappearance of the Rewah shales is not purely due to overlap, but partly to replacement. This plan of distribution—the tendency to a greater development of sandstone and a corresponding diminution in the thickness of the intercalated shales towards the actual limits of the formation—becomes more and more developed to the south-west: north of the Narbada near Hoshangabad the series consists of—

Upper Bhánrers	3,000
Lower "	500
Upper Rewahs	6,000
	9,500

And in the Dhár forest still further to the westward the whole formation consists of an enormous accumulation of sandstone, estimated at 10,000 feet, without distinguishable horizons. Mr. Mallet considers that this great sandstone formation probably represents all the groups

elsewhere so persistently separated. The fact that the greatest known accumulation of the upper Vindhyans occurs at the south-western extremity of the area seems to be opposed to the conjecture already made that the whole southern boundary is near the original limit of deposition; but, on the other hand, the absence of the finer deposits at this south-eastern corner of the basin suggests that the sandstones of this part of the basin were formed near the margin of the deposition area. The whole country to the south-west is covered by trap.

Boundary in Bundelkhand.—The border of the Vindhyans in Bundelkhand is more distinctly seen to be related to primitive features of the ground than can be proved in the case of the southern boundary. The bottom bed everywhere, except up the gorges, is the Kaimur conglomerate, forming a scarp over an undercliff of gneiss or of the intervening formations (lower Vindhyan or transition) already described. Where the river gorges afford sections at right angles to the boundary, the conglomerate is seen to thin out, disperse and vanish, other beds of the same group appearing below its horizon. On the Kén, fine shales of decided upper Vindhyan type are found in this position; so that the Kaimur conglomerate, though generally the bottom contact-rock of the upper Vindhyans in Bundelkhand, is not at the very base of the formation.

It is not in the Kaimur group only that evidence of thinning out against the gneiss of Bundelkhand is found. Towards the position where the upper Vindhyans have least suffered from erosion, at the head of the great bay of lower Bundelkhand, the outer (Kaimur) step of the plateau, in both the eastern and northern areas of the basin, gradually narrows, and the Rewah scarp approaches the glacis of the Kaimur scarp. The whole Rewah group does not, however, rise in this direction, as would happen if the basin were one of depression: the Rewah shales die out and the Rewah sandstone creeps up over the lower group, and for many miles forms an inconspicuous feature close behind the Kaimur scarp.

Boundary on the Ganges.—For the 120 miles between Allahabad and Sasseram (or more exactly between Chebu and Chainpur) the scarp of the Kaimur sandstone passes very obliquely across the axis of the eastern arm of the upper Vindhyan basin, connecting the boundary in Bundelkhand with that in the Son valley. For a great part of the distance the Ganges runs close to the plateau, and has, probably, repeatedly struck the base of the scarp at different points, as it now does at Chunár. Altogether, the position is one of special exposure, and no doubt a considerable area of the Vindhyans has been removed; no

underlying rock is exposed, the Kaimur sandstone being everywhere at the level of the river or of the alluvium. Still it does not seem probable that these rocks ever extended far in this direction; for the gentle inward slope of the beds which elsewhere has been found connected with other shoreward symptoms holds good for this part of the boundary also.

Arvali boundary.—Of a great portion of the north-western boundary in Rájputána, we know little more than the position. On the south-west, the Rájputána border seems generally to resemble that in the Son valley or Bundelkhand, and to show a well-marked three-fold division of the series, with a bottom sandstone resting indiscriminately on a variety of gneissic and transition rocks; but the ground has not been sufficiently examined to render it clear whether there are any signs of an original thinning out of the deposits such as has been described elsewhere. The features of this boundary to the north-east are against such a supposition, or at least do not suggest it; for long distances, as at Kerauli, the upper Bhánrer beds are brought into juxtaposition with the Arvali rocks by a great fault, outliers of the Rewah and Kaimur groups resting upon the transition (Arvali) rocks close by on the north-west side of the fault. It is plain that here the upper Vindhyans may once have extended indefinitely to the west. The same may be said of the northern prolongation of this arm of the basin; the whole series, seventy miles wide between Kerauli and Gwalior, strikes steadily to the north-east and so sinks gradually under the alluvial plains of the Jumna. A general section in this part of the basin, taken in a north-west direction through Sipri, gives the following dimensions for the several groups:—

	Feet.
Upper Bhánrers	2,000
Lower „	1,500
Upper Rewahs	300
Lower „	450
Upper Kaimur	250
	4,500

It should be recollected that the lower groups on this section are measured near the edge of the basin. They are probably much thicker, where covered by the Bhánrers in the centre of this area.

Petrology.—The general composition of the upper Vindhyan rocks is as uniform as their general arrangement. Although chiefly made up of sandstones, which are the coarser type of detrital deposits, the fineness of the rock throughout the formation is remarkable. With the exception of the Kaimur conglomerate, which is constantly present as a bottom-bed all round the boundary in Bundelkhand, pebble beds are of rare occurrence.

The Kaimur conglomerate is everywhere conspicuous through the prominence in it of bright red jasper pebbles, presumably derived from the jasper bands so abundant in the Gwalior formation. Where the Vindhyans rest upon the Gwalior beds, the rock is rather a breccia than a conglomerate, the included fragments being quite angular. The amount of this debris throughout such a length of outcrop, to such a distance from the nearest known area of Gwalior deposits, suggests the extensive removal of these peculiar rocks from the position now occupied by the gneiss.

There are general characteristics peculiar to each of the great sandstones. The Kaimur rock is fine-grained, greyish, yellowish or reddish-white, sometimes speckled brown; false-bedding is frequent; massive beds are abundant, but, on the whole, the bedding is of moderate thickness, sometimes flaggy and shaly. The Rewah sandstone is somewhat coarser, and generally presents a mixture of massive strata and false-bedded flags. The Bhánrer sandstone is softer than that of the lower bands, very fine grained and generally distinguishable as of deep red with white specks, or of pale tints with or without red streaks. The beds are generally thinner, and not more than 6 to 18 inches in thickness; but very massive beds also occur, as is exemplified by the great monoliths cut from the quarries at Rupbas near Barhatpur (Bhurtpore). Ripple-marking is common throughout the greater part of the Vindhyans, and occurs in great profusion and variety in the upper Bhánrers.

The different shale-bands of the upper Vindhyans do not present any constant distinctive characters. Thin, sharply-bedded, flaggy, silicious or sandy, sometimes micaceous shales, of greenish and rusty tints, form the prevailing type throughout. Purely argillaceous shales are rare.

The Bháurer limestone is perhaps the most variable rock of the series. Sometimes there is a considerable thickness, as much as 260 feet, of firm stone; elsewhere there is very much less, the carbonate of lime being apparently disseminated amongst the calcareous shales associated with the limestone and partly taking its place. The limestone is generally earthy and compact, of grey, yellow or reddish tints, sometimes purer and either compact or crystalline. It was in this rock at Nagode that fossils were thought to have been found long ago by Captain Franklin; they were supposed to be *Gryphæa*, and the rock was on this account assigned to the lias. It is not known what became of the specimens, and repeated search at the same locality has failed to verify the discovery. It is highly probable the objects discovered were not organic at all, and quite certain that the specific determination of them was fanciful.

The mutual relation of these sandstones, shales, and limestones is most intimate throughout the upper Vindhyan series. The passage upward, from shale into limestone, or into the great bands of sandstone, is always more or less gradual, by interstratification; while the change into shale at the top of the great sandstone beds is as generally abrupt.

Relation to the lower Vindhyans.—The relation of the upper Vindhyans to all contiguous formations is most unequivocal unconformity, except with the lower Vindhyans. That there is some slight unconformity here too, may be inferred. Overlap-unconformity has been shown to be extensive; but more than this would be presumable if only from the sudden highly contrasting and widespread change from the peculiarly fine deposits of the Rotás group to the Kaimur sandstone; and there is, in fact, evidence for some denudation-unconformity in the recognisable lower Vindhyan debris very sparingly found in the Kaimur deposits. Two deceptive features have, however, given grounds for exaggerating the evidence for a break between the upper and lower Vindhyans: before the entire equivalence of the upper shale and limestone of the Rotás group had been established, it had to be assumed that one or the other had been very extensively denuded before the deposition of the Kaimur beds, and this assumption involved much irregular superposition, although none could be detected in actual sections. The other deception is more important, because it involves the introduction of the higher degree of disturbance-unconformity—the greater or less contortion of the lower Vindhyans before the Kaimur period. This view rested upon the fact that the lower Vindhyans are often found sharply twisted in close proximity to the perfectly undisturbed Kaimurs in the Son valley. The upper Vindhyans themselves have, no doubt, undergone considerable flexure in this zone, as may be seen where they stretch across the main outcrop of the lower Vindhyans of the Son area, on the west at Bilheri and on the east at the Ghágar. But these broad undulations were not at first thought sufficient to include the frequently sharp flexures seen in the lower rock. This opinion had, however, to give way to the fact of invariable complete parallelism of the layers of the two formations whenever a contact could be observed, even in proximity to those contortions. It is important to dwell upon this observation, because some unconformities of this class, reported and insisted on elsewhere, rest upon no other evidence than that found to be fallacious in this case. It may even be suggested that such appearances might possibly be produced independently of any general disturbance of associated thick and thin, or hard or soft, deposits, merely by pressure from an adjoining elevated mass upon yielding underlying beds, as occurs in the familiar case of the 'creep' in coal mines.

Disturbance of the upper Vindhyans.—From the remarks in the preceding paragraph, it appears that the upper and lower Vindhyans have been affected by the same disturbing causes; and it has been said that any violent effects of disturbance are restricted to the south-south-east and the north-west margins of the basin. Two local exceptions to this rule may be noticed. In the Panwári ridge south of Tirhowan, the limestone (Rotás) is capped quite horizontally by Kaimur sandstone. The hill is more or less detached from the main plateau, and in the broken ground intervening, as well seen on the Paisuni and the upper valley of the Ohun, the sandstone is found dislocated and dipping in the most irregular fashion, quite inexplicable by any ordinary mode of disturbance. The displacement is probably due to the underground solution and removal of the Rotás limestone, and the consequent subsidence of the sandstone.

The other special instance of disturbance is not local in the same sense as the last, as it is probably only a symptom of much more that is concealed. It has been said that over the wide expanse of Vindhyan rocks between Gwalior and Nimach, the Bhánrer and Rewah beds lie quite flatly: and it has been presumed that to a considerable extent they stretch in this manner under the trap of Malwa. Close to Jhálra Patan, however, at the northern edge of the basaltic plateau, a sharp axis of disturbance passes from the south-east, beneath the trap, to the north-west, throwing up the Vindhyan strata in an anticlinal flexure, with dips of 70° on each side. Along this steep outcrop the sandstone weathers into long narrow ridges. This feature gradually dies out to the north-west. It is a hint that the disturbance which so violently affects the Vindhyans of the Dhár forest, extends far to the north under the basalt of Malwa.

The disturbance of the strata along the south-south-east border of the Vindhyan basin, to as far west as Hoshangabad, is plainly a recurrence, on the same lines, of the compression which had produced the contortion and cleavage in the adjoining transition and gneissic rocks. It seems to have taken different forms in different parts of the ground. Along the whole Son valley, there is little or no faulting in the zone of disturbance; but at the Son-Narbada watershed one or more faults occur at and close to the boundary, the east-north-east strike being remarkably steady throughout. Down the Narbada valley towards Hoshangabad, the dips in the Vindhyans become unsteady. At Hoshangabad, and again in the Dhár forest, there is a decided predominance of a north-westerly south-easterly strike; and as the east-north-east strike remains constant here in the contiguous transition and metamorphic rocks, it may be

sandstone, which has a gentle northerly slope. This limestone has a considerable extension to the north.

The condition in which the Vindhyans occur on the west side of the Arvali, much more than their state on the east side, proves them to be quite superficial as regards the rocks of the Arvali system, and that it is only in a secondary and derivative manner that they can be related to the Arvali mountain-system. Thus it is probably incorrect to speak of this Jodhpur sandstone as an outlier of the upper Vindhyan basin: it is more likely to be an independent representative of that formation. This interpretation implies that the Arvali axis is of pre-Vindhyan origin, and that altered Vindhyans do not form part of the Arvali rocks.

Allusion was made (p. 16) to some small Vindhyan outliers occurring on the Bundelkhand gneiss to the north and west. They differ much in character, and their peculiarities of composition may help to explain their apparently anomalous position. Although the gneiss reaches high up under the scarp of Kaimur conglomerate all round the western border of the area, which is described as a local edge of deposition, these small outliers occur at the level of the low country. If they agreed in composition with the rocks of the main area, which are so strikingly constant in this respect within that area, the fact might be at once explained by a subsequent change of level; but such is not the case.

The most curious of these outliers form a very broken chain running to south-south-east from close under the Pár scarp at Ládera (7 miles east of Antri) to Uchár on the Sindh river. Most of the exposures are quite level with the plain, or only to be seen in the beds of streams. In a few cases, as at Ládera and Pichor, they form narrow ridges up to 300 feet in height. The rock is sandstone of the upper Vindhyan type; and at the north end, close to the Pár scarp, it contains large angular pieces of the banded Morár shales; but elsewhere it is quite free from coarse debris of any kind. From many clear sections it is quite evident that these ribs of sandstone once filled a more or less continuous run of cracks, fissures, chasms, or small valleys in the gneiss. On both sides of the Pichor ridge the gneiss reaches well up on the sides of the sandstone mass, with vertical surfaces of contact. In the low ground at the point of the ridges, and in the small outliers, thin vein-like runs, 3 feet wide and upwards, of the sandstone, are well seen completely let in to the gneiss, as it might be filling an emptied trap-dyke, the rootlets of the wider chasm above. Even in the larger masses no bedding is visible; but sometimes at the edge of the mass planes of pseudo-lamination and even ripple-marked surfaces occur parallel to the vertical wall of gneiss. In every case observed, the lines of ripple were horizontal,

and the steep face of the ripple turned downwards. Some of these features seem to necessitate the supposition that the sandstone was let into this position by disturbance; but all the other circumstances have suggested the explanation given. The ripple may have been produced by dripping.

At Máharájpur, 10 miles south of Antri and 14 miles east of the Vindhyan scarp, there is a small group of hills, about 3 square miles in extent, formed of fine sandstone overlying about 50 feet of flaggy shales, both of Vindhyan type. The strata are greatly disturbed, but most irregularly, as if compressed from every side. Although so much broken, the rock is quite free from vein-quartz, which is also a general character of the Vindhyans as compared with the Gwalior strata.

The small hills of Sonár, 10 miles south-east of Narwar, and of Mohár, 16 miles farther in the same direction, present the same characters of composition and disturbance as at Máharájpur. At Mohár a trace of the Kaimur conglomerate occurs in the sandstone above the shales, which cover a considerable area round the base of the hill,[1] and may be looked upon as lower Kaimur.

A consideration of all the peculiar circumstances of these outliers would seem to suggest that they may represent small local basins of the upper Vindhyans. It seems that the process of denudation all round the Vindhyan area has been to decompose and remove the chemically-constituted metamorphic rocks which once formed high land around the sedimentary basins (whether this relation were original or due to subsequent warping of the surface), leaving the softer but undecomposable detrital rock to project where once had been depressions of the surface. This seems, indeed, to be a general law of denudation within appropriate limits and conditions.

[1] A remnant of the high-level rock-laterite occupies the summit of Mohár, but without any trace of trap. The importance of this observation will be shown in the chapter relating to laterite.

CHAPTER V.

PENINSULAR AREA.

GONDWÁNA SYSTEM.

Introductory remarks—Geological position and characters, and derivation of name — Area occupied — Fluviatile origin probable — Geological relations in India — Correlation with geological sequence in Europe and other countries — Contradictory evidence — Ancient zoological and botanical regions — Value of palæo-botanical evidence — Probable range of Gondwána system from permian to upper jurassic — Origin of Gondwána basins, and their relations to existing valleys — Surface of Gondwána area — Division of Gondwána system into groups — LOWER GONDWÁNA GROUPS — Tálchir group — Petrology — Boulder bed — Resemblance to volcanic rock — Resistance to weathering — Extent and thickness — Palæontology — Karharbári group — Reasons for distinguishing the group — Petrology — Relations to Tálchirs and thickness — Palæontology — Possible representation of group elsewhere — Damúda series — Sub-divisions— Palæontology — Relations to carboniferous flora of Australia — Relations to Karoo series of South Africa — Barákar group — Petrology — Relations to Tâlchirs — Thickness — Ironstone shales — Ránigauj group — Motur group — Bijori group — Kámthi and Hengir group — Mángli beds and their fossils — Panchet group — Petrology — Palæontology — Almod group.

Introductory remarks.—It has already been pointed out that there is, in the Peninsula of India, a remarkable deficiency of marine representatives of the palæozoic and lower mesozoic formations. Throughout the immense tract of land, bounded on the south by the sea, and on the north by the alluvial plain of the Ganges and Indus, there is, with the exception of the jurassic beds of Cutch (Kachh or Kach) and Jesalmir to the north-west, and a few outcrops of similar age along the east coast near Madras, Ongole, and Ellore to the south-east, no known marine deposit of older date than the cretaceous epoch.

Geological position and characters, and derivation of name.—The marine older and middle mesozoic, and probably the upper palæozoic formations of other countries are represented in the Peninsula of India by a great system of beds, chiefly composed of sandstones and shales, which appear, with the exception of the rocks just noticed along the east coast, to have been entirely deposited in fresh water, and probably by rivers. Remains of animals are very rare in these rocks, and the few which have hitherto been found belong chiefly to the lower vertebrate classes of

reptiles, amphibians, and fishes. Plant remains are more common, and evidence of several successive floras has been detected. The sub-divisions of this great plant-bearing series have been described under a number of local names, of which the oldest and best known are Tálchir, Damúda, Mahádeva, and Rájmahál, but the Geological Survey has now adopted the term Gondwána for the whole series. This term is derived from the old name for the countries south of the Narbada valley, which were formerly Gond[1] kingdoms, and now form the Jabalpur, Nágpúr, and Chhatisgarh divisions of the Central Provinces. In this region of Gondwána the most complete sequence of the formations constituting the present rock system is to be found.

Area occupied.—Taken as a whole, the Gondwána system has a wide extension in the Indian Peninsula; but its representatives have hitherto only been detected at one locality in Transgangetic India, *viz.*, along the base of the Himalayas in Sikkim, Bhután, and the Dalla hills.[2] Representatives of the highest Gondwána group are found in Cutch resting upon marine jurassic rocks and capped by neocomian beds; and in the desert which intervenes between Sind and Rájpútána, some rocks containing plant remains, and underlying jurassic limestones, closely resemble portions of the Gondwána series in lithological characters. Other representatives of beds high in the Gondwána series, in this case, however, frequently containing marine fossils, extend down the east coast. But with these exceptions, no representatives of the system are found in the Peninsula north of the line formed by the valleys of the Narbada[3] and Son, nor south-west of another line drawn from the sea at Masulipatam through Khamamet and Warangal north-east of Hyderabad, till it enters the trap area near Nirmal. The main areas of Gondwána rocks are in the Rájmahál hills and Damúda valley in Bengal, the Tributary Mahals of Orissa, Chhatisgarh, Chutia (Chota) Nágpúr, the upper Son valley, the Sátpúra range south of the Narbada valley, and the Godávari basin.

[1] For the information of non-Indian readers, it may be well to add that the Gond is one of the principal Dravidian, or so-called aboriginal, tribes, who are believed to have inhabited the country before the advent of the Aryan Hindu race.

[2] Mallet, Mem. G. S. I., Vol. XI, p. 1; and Godwin-Austen, J. A. S. B., 1875, XLIV, Pt. 2, p. 37. Perhaps the occurrence of a representative of the Rájmahál stratified traps on the flanks of the Khasi Hills might be quoted as a second instance. In this case, however, although the identification of the two sets of beds is highly probable, it has not been confirmed by the discovery of fossil evidence.

[3] Outcrops have been found in one place at least north of the river Narbada to the westward of Hoshangabad, but far south of the watershed. The Narbada, above the neighbourhood of Jabalpur, runs south of the general line of division, and Gondwána rocks occur north of the river.

Fluviatile origin probable.—It has already been mentioned that, with the few exceptions noted, the whole of the Gondwána series is believed to consist of strata deposited in fresh water, and the only question which arises is whether the beds are lacustrine or fluviatile. The coarseness of the rocks in general, the prevalence of sandstones, and the frequent occurrence of bands of conglomerate, render it improbable that these strata are of lacustrine origin, and the absence of mollusca almost throughout is, on the whole, rather more consistent with river than lake deposits, although it is difficult to account for on either hypothesis. The few fish and reptiles which occur might have inhabited either lakes or rivers, and the *Estheriæ*, which are common in several sub-divisions of the series, might either have lived in lakes or in the great pools and marshes which often occupy so large an area in broad river valleys. The plants might have been preserved amongst either lacustrine or fluviatile deposits, except that it is difficult to conceive the formation of beds of coal at the bottom of lakes; it is more probable that coal originated in marshy forests, such as frequently occur in the valley-plains of rivers. The physical characters of the strata, the frequent alternation of coarse and fine beds, the frequency of current-marking on the finer shales and of oblique lamination, due to deposition by a current, in the coarser sandstones, and the circumstance of the upper portions of a bed, such as a coal seam, being locally worn and denuded when a coarse sandstone is deposited upon it,—a phenomenon of frequent occurrence,—are quite consistent with the theory of deposition in a river valley, but opposed to the conception of lacustrine origin. A river constantly changes its course and deposits coarse sediment near its channel and finer materials from the overflow of its flood waters, the area within which each form of sediment is deposited varying frequently. In a lake the coarse deposits must be limited to the margin, and finer sediment accumulates away from the shore, whilst there is no current to sweep away the surface of a recently deposited coal or shale bed, and to throw down coarse sand in its place. On the whole, the evidence is decidedly in favour of a fluviatile origin for the Gondwána rocks, and it is probable that they were deposited in a great river valley, or series of river valleys, not unlike those which form the Indo-Gangetic plains at the present day. There is a possible exception in the lowest beds of the series, the fine silts which form the basement beds of the Tálchir group. These may be of lacustrine origin, but there is no clear proof that they are, and their remarkably persistent character throughout an immense tract of country is rather opposed to the idea of their having been formed in a lake or a series of lakes.

Geological relations in India.—Concerning the relations of this great series to older and newer formations but little can be said. No older fossiliferous deposits are known in the area to which the Gondwána rocks are restricted, and wherever these rest upon any older formation, there is complete unconformity between the two. With the upper Vindhyans, which are, in descending order, the next series in the Peninsula of India, the Gondwánas have nowhere been found in contact, the area occupied by the former being outside that to which the latter are restricted, but upper Vindhyan pebbles are occasionally found in Gondwána rocks. The Tálchir and Damúda formations in the country south of Nágpúr, on the Godávari below Sironcha, and in the Mahánadi valley near Sambalpúr, occasionally rest unconformably upon strata belonging to the lower Vindhyan series, but in general the Gondwána beds are found to have been deposited upon metamorphic rocks.

On the other hand, the rocks of the Gondwána series are but rarely covered at all by a higher formation, except in the Narbada valley and the Nágpúr country, where the Deccan traps and their associated infratrappean formation, the Lameta group, rest unconformably upon the various sub-divisions of the Gondwána series from the lowest to the highest. There are, however, localities in India in which sedimentary formations of cretaceous age rest upon upper Gondwána beds. The first of these is in Cutch (Kach or Kachh), where the Umia (Oomia) group, containing some fossil plants found also in the uppermost Gondwána beds in the Narbada valley, underlies a stratum containing *Cephalopoda* of upper neocomian (Aptian) age. The second is in the Narbada valley near Burwai, where Bágh beds (upper greensand or Cenomanian) rest unconformably on representatives of the Mahádeva formation (upper Gondwána). The remaining two localities are near the east coast; one is in Southern India, at Utatur north of Trichinopoly, where the plant beds containing Rájmahál fossils underlie the Utatur (Cenomanian) group, unconformably in places, but elsewhere with apparent conformity; and lastly near Ellore. Here also the upper Gondwána beds contain Rájmahál plants, and marine fossils of upper jurassic age occur in the higher layers, whilst the age of the strata resting unconformably upon the Gondwána strata is not equally well defined; the overlying beds consist of two fossiliferous bands, one underlying a flow of basalt, believed to belong to the Deccan trap series, the other interstratified between the lower basaltic flow and a higher one. The igneous beds, like the Deccan traps elsewhere, are believed to be of upper cretaceous age, but the fossils in the upper or intertrappean bed differ from those in the lower or infratrappean, and it has not hitherto been practicable to refer either to a

definite horizon. Neither bed, however, can be older than upper cretaceous.

Correlation with geological sequence in Europe and other countries.—The attempt to correlate the Gondwána series with the typical sequence of sedimentary formations in Europe has proved a long and difficult undertaking, and cannot even now be considered as definitely decided, although some light has been thrown upon it by the researches of Dr. Feistmantel, who is engaged in examining the fossil plants from the different Indian groups. He ascribes to the whole series an age ranging from lower trias or Bunter (Tálchir and Damúda) to middle jurassic or Bathonian (Jabalpur and Umia). His determinations, however, being founded exclusively on a comparison of the Gondwána fossil plants with those of European formations, are very frequently opposed by other fossil evidence. The Umia beds of Cutch, for instance, the flora of which is considered by Dr. Feistmantel of the same age as that of the Jabalpur group, which is the highest Gondwána sub-division, contains several plants found also in the lower oolites of Yorkshire, but the *Cephalopoda* of the marine beds which immediately underlie the Umia plant beds, and are to some extent interstratified, have been shewn by Dr. Waagen to be uppermost Oolite (Portland and Tithonian) forms, and to be separated by two distinct groups of beds, each with a well-marked fauna, from the underlying strata in which lower oolitic *Cephalopoda* occur. In the Damúdas and their representatives, on the other hand, although a few fossil plants are allied to triassic species, several of the most abundant and characteristic forms are unknown in the trias of Europe, but are represented by the same or nearly allied plants in the coal measures of Australia, the lower portion of which is certainly of carboniferous age.[1]

Contradictory evidence.—It is probable that the exact relation of the different groups composing the Gondwána series to rocks containing a similar flora in Europe and in other parts of the world will never be satisfactorily determined until the geology of the intervening regions is better known. As an example of the difficulties presented in the present state of our knowledge by the contradictory evidence afforded by the fossils of one group, the case of the Kota-Maleri beds may be cited.[2] The Kota beds consist of limestone, and contain remains of fish which have a liassic facies. The Maleri (or Maledi) beds have yielded two reptiles, *Hyperodapedon* and *Parasuchus*, and a fish, *Ceratodus*, all of which are closely allied to European triassic forms. In these Maleri beds, some

[1] For some additional details see p. 119. Further information as to the age of Gondwána beds will be found in Mem. G. S. I., Vol. II, p. 299; Vol. III, p. 197; Records G. S. I., IX and X, &c., &c.; and Q. J. G. S., 1855, p. 345; 1857, p. 325; and 1875, p. 519.

[2] For further details see pp. 151-156.

plants have been obtained common to the Jabalpur and Sripermatur groups, the flora of the former of which has been shewn to be in part identical with that of the Umia group of Cutch. The singularly contradictory evidence of age afforded by this Umia flora has already been mentioned. The Kota beds, with their liassic fish, have now been shewn to be so closely connected with the Maleri clays and sandstones, containing triassic reptiles and fish, and jurassic plants, that both are classed in the same group.

Ancient zoological and botanical regions.—Assuming that the association of similar marine forms in the rocks of distant countries—for instance, in the carboniferous limestone of Europe, the Punjab in India, and Australia—implies that the rocks are of contemporaneous or nearly contemporaneous origin, the remarkable combination of fossils in the Kota-Maleri beds appears to shew that, in mesozoic times, there was a wider diversity in the forms of terrestrial life inhabiting distant regions at any given period, than there was in the faunas of the surrounding seas. This view is in accordance with the very similar conditions now found prevailing upon the earth's surface, there being a much greater difference between the terrestrial faunas and floras of Africa, Australia, and America, for instance, than there is between the animals inhabiting the Atlantic, Indian, and Pacific Oceans. It is a common circumstance, moreover, to discover fossil remains of animals without any living representatives in neighbouring lands, but which are nearly allied to forms still existing in distant countries. Thus extinct genera of lemurs are found in the older tertiaries of Europe and North America, whilst the living forms of the order are restricted to Africa, Madagascar, South-Eastern Asia, and the Malay Archipelago. The genus *Ceratodus*, also, which is not rare in the older mesozoic strata of Europe, and the occurrence of which at Maleri has just been mentioned, has recently been found represented by living species in Australia. There appear, in short, good reasons for believing that the terrestrial area of the world was divided into zoological and botanical regions in past time, as it is at present, and the fauna and flora of India may have differed, at times, more from those then existing in distant countries, than from the animals or plants which prevailed in the same distant regions at a different geological epoch.

Value of palæo-botanical evidence.—At the same time, although it is unsafe to consider Indian formations of contemporaneous origin with those found in other countries on the evidence of their terrestrial flora or fauna alone, the remains of plants furnish most valuable evidence as to the representation of different groups by each other within the Indian area, because it is reasonable to suppose that the range in time of each species and genus in neighbouring countries was nearly the same. It is

consequently reasonable and safe to refer the Kota-Maleri beds to the same approximate horizon as the Jabalpur group, or to a slightly lower position, corresponding to that of the Sripermatur beds, although it is not safe to refer the Kota-Maleri group to the lower oolites on account of its plant remains, to the trias on the strength of its reptiles, or to the lias, because of the fish it contains.

It should, however, not be forgotten that plant remains are usually fragmentary, and they are but rarely so well preserved or so characteristic as remains of animals. The most important portions of the plant—those connected with fructification—are usually wanting, and the leaves and stems, which are most commonly found fossil, are far less characteristic, both because those belonging to different species or genera and even to different orders resemble each other closely in many cases, and also because leaves and stems are liable to great variation even in different parts of the same plant. A single fairly preserved molluscan shell, especially a Brachiopod or a chambered Cephalopod, one cup of a coral, or the test of an Echinoderm, and frequently a single tooth or bone of a fish, reptile or mammal, affords far safer indication of affinities than the leaf of a phanerogamous plant or the barren frond of a fern, however well preserved. But in all cases of this kind evidence is cumulative, and the probabilities in favour of identification increase in geometrical proportion with the number of forms. If one leaf or stem be found which appears to be the same as a species found elsewhere, we may fairly suspend our judgment, but our confidence in the identification increases rapidly when several leaves, for instance, belonging to different genera, found together in one formation, correspond closely to forms similarly associated in beds at a distance.

Probable range of Gondwana system from permian to upper jurassic.—Some details of the flora and fauna will be given with the general descriptions of the different groups. Taking the whole evidence into consideration, different writers on the affinities of the lowest Gondwána beds have assigned these formations to various epochs from carboniferous to lower triassic, and the highest Gondwánas have alternately been assigned to lower oolite and wealden. The truth may very probably lie between the two extreme opinions in each case. A slight, but very valuable, suggestion has been founded[1] on the evidence of ice action at the base of the whole Gondwána system, and on similar evidence in other countries, and especially in England, in rocks belonging to the permian period. Assuming, as it is perfectly justifiable to do, after the enormous accumulation of evidence now available, that the whole world has, in late geological times, passed through a cold period, it is not unreasonable to suppose that similar epochs of diminished

[1] H. F. Blanford, Q. J. G. S., 1875, Vol. XXXI, p. 528, &c.

temperature have recurred in past ages, and that one of these eras of glacial conditions coincided with the permian age. The singular poverty in organic life of the permian and lower triassic rocks throughout many parts of the world, and the extensive change which took place about this period in the fauna and flora, may be due, in part at least, to the occurrence of a great diminution in the temperature of the earth's surface. With this additional suggestion to support it, the reference of the lowest Gondwána strata to the permian epoch appears to agree better with the existing state of knowledge than any other, and it will be equally safe to class the Umia beds of Cutch as upper jurassic, the uppermost true Gondwána beds of Jabalpur being perhaps a little older. But it must not be considered that this determination of the age of the Gondwána series is final, for additional evidence may, and very probably will, lead to modifications. At present it is only practicable to select, from amongst a number of conflicting views, those which appear least in discordance with the evidence hitherto obtained.

Origin of Gondwana basins and their relations to existing valleys.—The manner in which the areas of Gondwána rocks are distributed throughout the country is peculiar, and there is still some difference of opinion concerning the interpretation to be placed on their mode of occurrence. As a general rule, these rocks are found occupying basin-shaped depressions in the older formations, and such depressions sometimes, though not always, nor even generally, correspond to the existing river valleys. Occasionally the basins of Gondwána beds are scattered over the surface of the country, as in Birbhum (Beerbhoom), and in this case there can be no doubt of their representing the undenuded remains of strata which were once continuous over a much larger area. Whether the basins now remaining owe their preservation to disturbance of their originally horizontal position, and to their having been preserved from denudation through having sunk to a lower level than neighbouring portions of the same bed, or whether they were originally deposited in hollows in the older beds, is a point on which opinions differ. There can be no question that the former is the explanation of these basins having been preserved in some instances; but cases may also be cited in favour of the latter view, and it is certain that the Gondwána beds were originally deposited on an uneven surface.

A few instances will suffice to shew the phenomena presented in the Damúda valley in Western Bengal, where some of the most important and best known Gondwána coal fields occur. A number of detached basins are found, all in low ground, on the banks of the river, and all presenting the very remarkable peculiarities that the lowest groups

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appear on the northern side of the basin, that there is a general dip from north to south, and that all are cut off abruptly on the southern edge, which is in most cases along a straight or nearly straight line. Similar geological relations exist in many other areas, although the beds are not always, as in the Damúda area, confined to the valley of a single river. Thus, in the great basin of South Rewah and Sirgúja, again in the Sátpúra area, and especially in the Tálchir field in Orissa, the rocks dip from one side of the basin, and are cut off on the other; but in all these cases the general dip is north, not south, and the beds are abruptly cut off along the northern border. The exact direction of the abrupt east and west boundaries vary, but they are always the same, or nearly the same, throughout each tract of country: that is to say, the boundaries of different fields are parallel to each other, and they are also, as a rule, identical in direction with the foliation of the underlying gneiss. In some cases, and especially in the northern part of the great area which occupies so large a portion of the Godávari valley, both boundaries, which, in the last-named case, run nearly north-west to south-east, are straight, nearly parallel and abrupt.

These abrupt boundaries are almost invariably accompanied by considerable disturbance of the beds in their neighbourhood. In some cases there is strong evidence that such boundaries are great faults, one of the best proofs being that the fault occasionally divides, as along the northern edge of the Tálchir field, and beds belonging to the lowest group are exposed between the different sub-divisions of the main dislocation; the lowest Gondwána group (the Tálchir in the instance mentioned) being faulted against Kámthi beds, much higher in the Gondwána series, on one side, and against metamorphics on the other. In some cases, as along the boundary of the Tálchir field, and also on the eastern portion of the northern boundary in the Sohágpúr field, the line of fault is marked by a breccia, containing fragments of the Gondwána sandstones. It is considered by several of the Geological Survey that all the fields which are bounded by an abrupt line cutting them off on one or both sides (and these, as will be seen, comprise a very large majority of the basins known) occupy areas of depression produced, subsequently to the deposition of the beds, by a great fault along the abrupt boundary. It is further urged that the present connection of existing river valleys with these Gondwána areas depends upon the fact that the Gondwána rocks being much softer than the Vindhyan, transition, or metamorphic beds upon which they rest, the rivers have worn their way through the easiest channel; that, in short, the existing drainage, so far as it coincides with the distribution of the Gondwána rocks, has been determined by

the disposition of those rocks produced by disturbance and denudation, and has no necessary connection with their original areas of deposition.

A different view is held by others. They consider that there is, with a few exceptions, no sufficient evidence of faulting, that the appearance of straightness in the boundaries is partly fallacious and due to the rocks being ill seen at the surface, that the abrupt boundaries are caused by the deposition of the Gondwána rocks against cliffs forming the original sides of river valleys, and that the present disposition of the beds is a close approximation to that of the original areas in which they were deposited. They especially point out that in one instance, in the Sátpúra area, Gondwána rocks overlap the abrupt boundary in places. They consider further that the vertical development of the different groups varies so much within small distances, that there is no reason to believe that any great thickness of beds abuts against the abrupt cliff-like boundaries, and that there is evidence in some cases that the different groups thin out towards the margins of the existing basins. They conclude that the present river valleys differ but little from those which existed in mesozoic times.

It is possible that there may be some truth in both views. It should be remembered that the conflict of opinion in this case is between observers, who have chiefly been engaged in mapping widely-separated regions, the uniformitarian view, that the present basins closely correspond to ancient areas of deposition, being supported chiefly by observations made in the Sôn and Narbada valleys, and the opposite opinion, that the present Gondwána basins are chiefly due to faulting, being held by geologists who have especially studied the Gondwána rocks of Bengal, Orissa, and the Godávari valley. It is possible that there may be a difference in respect to the amount of disturbance undergone between the upper and lower Gondwána series: such a difference has been shewn, on very good evidence, to exist in Western Bengal, where trap dykes, supposed, with great probability, to be of upper Gondwána age, are newer than the dislocations affecting the lower Gondwána beds; and it is by no means improbable that a similar disturbance may have affected the lower members of the Gondwána system in other parts of India before the deposition of the uppermost groups. The strongest arguments against the existence of faults along the abrupt boundaries of the various Gondwána fields is founded on the fact, that in the Sátpúra field to the south of the Narbada valley certain of the uppermost Gondwána beds overlap the boundary; but this may be due to the circumstance that the supposed line of fault, which cuts off the field on the northward throughout the greater portion of its extent, is more ancient than the

topmost groups of the Gondwána series. One important observation in favour of the basins in the Damúda valley in Western Bengal having been disturbed and depressed to their present level subsequently to the period of their deposition, or, conversely, of the continuation of the same beds having been raised to a higher elevation, is to be found in the presence of Tálchir and Damúda beds on the Hazáribágh table-land, immediately north of the Damúda valley, at a height of about one thousand feet above the surface of the same rocks in the valley itself, and in the existence of fragments, apparently derived from lower Gondwána beds, in a conglomerate at a similar or higher elevation on the Chutia Nágpúr highland to the southward. Some of the abrupt boundaries to the south of the Gondwána basins in the Damúda valley, and especially the southern margin of the Karanpura and Bokáro fields, are shewn to be long lines of fault by independent evidence, which will be mentioned in the descriptions of those areas. Another difficulty in the way of admitting that the abrupt boundaries of the Damúda fields are due to deposition against inland cliffs is to be found in the improbability that all such precipices should be found on one side of a river valley—the south in this instance,—and none on the northern bank. It may be questioned whether anywhere amongst gneissose rocks such a series of straight and parallel cliffs can be found as must be supposed to have existed in the Gondwána epoch, along the southern side of the Damúda valley, if the abrupt southern boundaries of the various fields are to be explained otherwise than by faulting. At the same time, it is possible that the extent of the faults may have been unintentionally exaggerated by the surveyors who mapped the coal-fields, and that, owing to irregularities in the thickness of the various groups, the whole vertical extent of the beds, at any particular locality, may be less than was at first supposed. In the descriptions of the different fields to be given in subsequent pages, the views of the original describers will, to a great extent, be followed; but it must be understood that these views are not universally conceded, and that further examination of the ground may cause a considerable modification of the opinions hitherto held.[1]

Surface of Gondwana areas.—The tracts of country occupied by rocks of the Gondwána series are, as a rule, covered with a poor sandy soil

[1] It should, perhaps, be stated that the two authors of the present Manual hold different views in this matter; Mr. Medlicott believing that the present basins approximate closely in form to the original river valleys, whilst Mr. Blanford thinks that the present Gondwána areas are remnants of more extensive deposits preserved from denudation through being let down by faults. Both agree in considering that the Gondwána beds were originally river-deposits.

and ill suited for cultivation. The result is that in many parts of India they form wild uninhabited forests. Such tracts are always the last to be surveyed topographically, and, as a rule, minor details are omitted on the maps prepared. The upper Gondwána rocks are principally sandstones, and decompose into loose sand, which covers the whole surface of the country and greatly conceals the rocks. These two circumstances—deficiency of maps and concealment of the surface—have combined to delay the Geological Survey of the important Gondwána formations, and to render the examination of the beds exceptionally tedious and difficult.

Division of the Gondwana system into groups.—The groups of which the Gondwána system is composed vary greatly both in number and mineral character in the several isolated areas in which they are found, the variation being much greater amongst the middle and upper than amongst the lower members of the series. The two lowest Gondwána groups, Tálchir and Barákar, preserve their mineral character almost unchanged throughout the area in which the lower Gondwána beds are known to occur. The inferior sub-divisions of the system, the Tálchirs and Damúdas, consist largely of shales, whilst the uppermost formations are chiefly composed of coarse sandstone, grit, and conglomerate.

The system may be divided into an upper and a lower series; the Tálchir, Damúda, and Panchet groups, with their equivalents, being referred to the latter; the Rájmahál, Mahádeva, and Jabalpur to the former. The distinction is generally marked palæontologically by the prevalence of equisetaceous plants in the lower sub-division, and of cycads and conifers in the upper,[1] ferns being found commonly in both. Some *Equisetaceæ* occur, however, in the upper Gondwánas, and several species of cycads and conifers in the lower, but the genera are in most cases distinct in the two subdivisions.

In consequence of the variation which is exhibited by the members of this system, it is necessary to describe, in some detail, the characters presented in the different areas in which it is represented. This is also rendered desirable by the economic importance of the Damúda group, from which nearly all the coal extracted in India is obtained. The attention of the Geological Survey has, from its first commencement, been especially directed to the coal-producing beds and their associates, and, in consequence, a large number of the coal-fields have been carefully and systematically surveyed.

Before proceeding to these details, however, it will be useful to describe the groups, and to explain their names. The following table shews the principal groups represented in each area, and their representation of each other so far as their connections have hitherto been traced.

[1] The Mahádeva formation has, however, hitherto proved almost unfossiliferous.

Table shewing the supposed representation of Gondwána groups by each other.

	General sequence.	I. Rájmahál.	II. Birbhum, Deogarh. and Karharbári.	III. Damúda valley.	IV. Són, Mahánadi, and Bráhmani valleys.	V. Sátpúra region.	VI. Godávari valley.	VII. East Coast region.	Cutch.
UPPER GONDWANA.	Cutch and Jabalpur.	...	...	...	...	...	Chikiala ...	Tripetty ...	Umia.
		...	..	...	Jabalpur ...	Jabalpur ...		Sattavedu ? ...	Katrol.
		...	...	...		Bagra ...	Kota-Maleri ...	Ragavapuram and Sripermatur.	...
	Rájmahál and Mahádeva.	Rájmahál ...	...	..	Mahádeva ...	Denwa ...		Golapilli ...	...
		Dubrájpur ...	...	Mahádeva ...		Pachmari ...	...	...	...
LOWER GONDWANA.	Panchet ...	...	...	Panchet ...	...	Almod ? ...		...	...
		...	...	Raniganj ...	Kámthí (Hengir)	Bijori ...	Kámthí (including Mángli).	...	...
	Damúda ...	...	...	Ironstone shales	...	Motur ...		...	...
		Barákar ...	Barákar ...	Barákar ...	Barákar ...	Barákar ...	Barákar ...	...	...
		...	Karharbári ...	...	...	...	...	...	...
	Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	...	...

In proceeding briefly to consider these groups in detail, it is more convenient to commence with the oldest.

I.—LOWER GONDWÁNA GROUPS.

Talchir.—This group, which everywhere when present—and it is rarely absent over a large area—forms the base of the Gondwána series, was thus named from its having been first clearly distinguished in the small district of Tálchir,[1] one of the tributary mahâls of Orissa.

Composition and petrology.—The Tálchir group consists in general of fine silty shales and fine soft sandstone. The shales are usually of a greenish-grey or olive colour, sometimes slaty; they are of exceedingly fine texture and traversed by innumerable joints, and they break up into minute, thin, angular fragments, sometimes elongate or acicular, which cover the surface of the ground in places. Occasionally the shales have a dull Indian red colour, but this is not common. They are frequently mentioned in the Survey reports under the name of mudstones and needle-shales; not unfrequently they are somewhat calcareous, and in places large concretionary masses of impure carbonate of lime have been found amongst them.

The most characteristic sandstones are soft, fine, and homogeneous in texture, composed chiefly of quartz and *undecomposed* pink felspar, and are pale greenish-grey, buff, or pale pinkish, almost of a flesh tint. They are frequently rather massive, though distinctly stratified, but they are also commonly interstratified in thin layers with the shales. In many places they break up on the surface, where exposed, into polygonal fragments 3 or 4 inches in diameter; hence they have been called tesselated sandstones.

These beds pass into coarser sandstones of less marked character, which are sometimes, though rarely, conglomeratic, and which vary in colour. It is an almost invariable rule, contrary to what is found to be the case in most rocks, that in the Tálchir group the beds of finest texture, the shales, are found at the base, and that the sandstones are higher in position; the coarser sandstones, moreover, overlying those of finer texture. A thin coal seam has been found amongst the Tálchir beds in the Jhilmilli field, in Sirgúja, but, as a rule, this formation is distinguished by the absence of coal seams, and even of carbonaceous shale.

There are three peculiarities of the Tálchir group which still require notice, as all of them are of considerable importance.

Boulder bed.—The first is the frequent occurrence, amongst the shales and fine sandstones, generally towards the base of the group, but very

[1] Mem. G. S. I., I., p. 46.

frequently some hundreds of feet above the bottom, of pebbles and boulders, always rolled and usually well rounded, varying in size from small fragments half an inch or an inch across to huge blocks 15 feet in diameter and 30 tons in weight; fragments from 6 inches to 3 feet in diameter being common. The distribution of the boulders is most irregular; in some parts of the area occupied by Tálchir beds, none are to be found over many square miles of country, but generally some are met with at intervals, and occasionally large numbers occur within a limited tract.

In very many instances there is every probability that the boulders have been transported from a distance, no rocks of similar character being found in the neighbourhood. If only one or two such cases had been observed, it might be supposed that the rock from which the blocks were derived had formerly existed in the immediate vicinity, but had been removed by denudation; the cases, however, in which there is reason to believe that the rounded blocks have been transported from afar are so numerous that the theory of denudation cannot be accepted. The boulders, it should be remembered, are frequently found imbedded in the finest silt. It is evident that deposition from water in rapid motion is here out of the question; any stream which could move and round the boulders would have swept away the silty matrix in which they are deposited, and the only suggestion as to the cause of their occurrence which appears satisfactorily to account for their presence is to suppose that they have been originally rounded by torrents and then transported to their final position by ground ice. This theory has received strong confirmation by the discovery of smoothed and scratched surfaces on some of the large boulders found on the banks of the Pem River, about 10 miles west-south-west of Chánda, Central Provinces.[1] The surface of the lower Vindhyan limestone rock underlying the Tálchirs was also in this case found to be polished, scratched, and grooved.

Resemblance to volcanic rocks.—The second peculiarity is the remarkable resemblance to a volcanic rock occasionally presented by the more compact forms of shale and by a variety of the sandstone. So great is the similarity between the shale and a consolidated volcanic ash that two experienced surveyors have at different times marked the beds as trappean, whilst the sandstone occasionally simulates a decomposed basalt in colour and mode of weathering.

Resistance to weathering.—The third noteworthy feature of the Tálchir beds is their power of resisting disintegration, and, provided of course they are not covered by alluvial deposits derived from other rocks,

[1] Oldham, Mem. G. S. I., IX, p. (324); Fedden, Rec. G. S. I., VIII, p. 16. The question of the origin of the Tálchir boulder bed is discussed in the Memoirs, *l. c.*

the extreme barrenness of the ground, where they appear at the surface, is a natural consequence of their not decomposing to form soil. In many places along the edges of the coal-fields, where the Tálchir beds occupy the ground, it is possible to walk for miles through very thin jungles, free from grass, over a surface composed entirely of the finely comminuted greenish-grey shales.

Extent and thickness.—The Tálchirs preserve all their peculiarities throughout the area in which they occur; this is an enormous tract of country, extending from the flanks of the Rájmahál hills to the Godávari, and from the Ráníganj field on the borders of the alluvium of Lower Bengal to the neighbourhood of Hoshangabád, Nágpúr, and Chánda.

The thickness of the Tálchirs nowhere appears to exceed about 800 feet, their extreme measurement where fully developed in part of the Ráníganj coal-field.

Palæontology.—The fossils[1] hitherto discovered in the Tálchir rocks are very few in number. Of animal remains only the wing of a neuropterous insect and some annelide tracks have been discovered, whilst the plant remains consist of three ferns, *Gangamopteris cyclopteroides*, *G. angustifolia*, and a form of *Glossopteris*, represented by a single fragment, some equisetaceous stems, and a plant, hitherto not distinctly identified, resembling *Noeggerathia*[2] *hislopi*. The only evidence of vegetable life hitherto found has been in the higher beds of the group, and there is a remarkable absence of plants in the lower shales, which are admirably suited for preserving vegetable impressions. Even in the upper beds of the group fossils are of singularly rare occurrence.

Probable conditions of deposition.—Reference has already been made to the possibility of a lacustrine origin for the Tálchir beds, or at least for the lower portion. The chief reason for suggesting that these beds may have been deposited in lakes is the great thickness of very fine sediment accumulated at the base of the group, and the very frequent occurrence of much finer beds below than above. The latter, on the hypothesis of a lacustrine origin, may be explained by the gradual silting up of a lake basin, in which fine sediment would be deposited at a distance from the margin, whilst coarser beds would be thrown down by rivers as their deltas advance into the lake and fill it up. This evidence, however, is quite insufficient alone to prove that the Tálchirs are a lacustrine deposit,

[1] The fossil plants occurring in this and other groups of the Gondwána system have been chiefly determined by Dr. Feistmantel.

[2] The species here and elsewhere called *Noeggerathia* are, in all probability, not congeneric with the type of that genus, a carboniferous plant. They have lately been referred to *Zamia* by Dr. Feistmantel, but as this reference to a living genus is temporary, it is perhaps as well for the present to preserve the original generic name.

and it is at least equally probable that they were formed in a river valley like the overlying members of the Gondwána series.

To account for the climatal conditions which, in a tropical country, could be consistent with the occurrence of winter cold sufficiently intense to cause the formation of ground ice, it has been suggested that the Tálchir beds were formed on a lofty plateau like that of Tibet. The chief obstacle to the acceptance of this hypothesis is the difficulty of believing that a change in elevation, sufficient to account for the absence of all glacial conditions in the overlying Barákars, could have been effected without a much greater amount of disturbance than has taken place between the deposition of the two groups. The occurrence,[1] in rocks occupying the same approximate position at the base of the South African representatives of the Gondwána series, of similar boulder beds, which by some writers are attributed to ice action,[2] the suggestion of a like origin for the breccias of the English permian rocks,[3] which are probably of the same age, and the probability that the whole globe may have passed through a period of low temperature at the close of the palæozoic epoch, have already been mentioned.[4]

Karharbari Group,—Reasons for distinguishing the group.— Hitherto, in the publications of the Geological Survey, the coal-bearing rocks of the Karharbári coal-field have been assigned to the Barákar group, on account of their mineral character and their position immediately above the Tálchir beds. The examination of the Karharbári fossil flora has, however, shewn that whilst all the species, known to be found in the Tálchir beds, are represented, one of them, *Gangamopteris cyclopteroides*, being the commonest fossil of the Karharbári beds, many of the common Damúda fossils are rare or wanting, and several very remarkable species are found which have not hitherto been detected in the Damúda series. The peculiar excellence of the coal and its superiority to that obtained from the majority of the Damúda seams, have led to extensive mining operations in the Karharbári field, and it has consequently been possible to obtain good collections of the fossil plants.[5] It has also been noticed that the coal of Karhar-

[1] Mem. G. S. I., IX, p. (325), 31; Q. J. G. S., 1875, p. 529, &c.

[2] Sutherland, Q. J. G. S., 1870, p. 514; Griesbach, Q. J. G. S., 1871, p. 58. By other writers, however, this rock is said to be volcanic (Q. J. G. S., 1867, pp. 142, 172); but it is difficult to reconcile this view with the account given by Dr. Sutherland and Mr. Griesbach The latter writer suggests that two distinct rocks—a melaphyr and the boulder bed proper —have been confounded.

[3] Ramsay, Q. J. G. S., 1855, p. 185.

[4] H. F. Blanford, Q J. G. S., 1875, pp. 530, &c.

[5] These have been chiefly collected by Mr. I. J. Whitty, Superintendent of the East Indian Railway Company's collieries at Karharbári.

bári differs in structure from that of the Damúda series generally, and a partial re-examination of the field appears to justify the inference that there is also a slight distinction between the Karharbári and Barákar sandstones, although it is as yet uncertain whether a passage may not eventually be found between the Karharbári group and the Barákars. The palæontological evidence hitherto obtained tends, however, to connect the former with the Tálchir group, and it appears best, for the present, to keep the rocks of Karharbári distinct from the overlying Damúda series, under the name of the coal-field in which alone they are known to occur.

Petrology.—The rocks of the Karharbári group consist almost solely of sandstones, grits, and conglomerate, with seams of coal. Very little shale occurs, the little which exists being associated with the coal-seams. The sandstones are mostly white, grey, or brown, and felspathic; they are often gritty and conglomeratic from containing large fragments of felspar and pebbles of quartz. The chief distinction between the constituents of the grits and conglomerates forming the Karharbári group, and those which make up so large a portion of the Barákars, is that in the former, and especially in the coarser grits and conglomerates, a large proportion of the fragments of felspar and quartz are angular or subangular, whereas in the Barákars the pebbles are, as a rule, particularly well rounded. The coal of Karharbári is rather dull-coloured and tolerably homogeneous in structure, the layers of very bright jetty coal, which are so conspicuous in the Damúda seams in general, being few and ill-marked. So far as mining has hitherto proceeded, the coal-seams appear to be somewhat variable in thickness, but to undergo very little change in composition throughout the small field in which they are found, and of which a description will be given on a future page. Some of the seams, both in the Barákar and Rániganj sub-divisions of the Damúda series, furnish fuel equal in quality to that extracted at Karharbári, but they are much more distinctly laminated.

Relations to Talchirs and thickness.—The Karharbári beds rest in apparent conformity on the Tálchirs, but the former completely overlap the latter in places within the limits of the little Karharbári field, and the mineral characters of the two groups are strongly contrasted. In the west of the Karharbári basin the Tálchirs attain a thickness of about 500 or 600 feet, whilst within a distance of less than 4 miles to the eastward, the Karharbári beds rest upon the gneiss. It is probable that the highest rocks seen within the coal-field may be of Barákar age, and there is some slight appearance of the Karharbári beds being overlapped by these higher strata, but the overlap is not clear. The whole thickness of the Karharbári group is probably about 500 feet.

Palæontology.—The only fossils hitherto procured from the Karharbári group consist of plants. The following species have been identified[1]: the most abundant are indicated by a †; those marked thus § are found also in the Tálchirs; the species thus marked || in the Damúdas.

EQUISETACEÆ—

|| *Vertebraria indica.*—Very rare.
Schizoneura, sp. near *S. meriani.*

FILICES—

† *Neuropteris valida.* Pl. VI, fig. 5.[2]
§ † *Gangamopteris cyclopteroides.* Pl. III, fig 1.
§ *G. angustifolia* and two other species of *Gangamopteris.*
|| *Glossopteris communis.*
G. decipiens.
Sagenopteris stoliczkana.

CYCADEACEÆ—

Glossozamites stoliczkanus.
|| *Noeggerathia (Zamia) hislopi*, var.
N. (Zamia), sp.
A peculiar genus, unnamed.

CONIFERÆ—

† *Voltzia heterophylla.* Pl. VI, fig. 7.
Albertia, sp. near *A. speciosa.*

The relations of this flora to the lower triassic or Bunter (*Grès bigarré*) flora of Europe are very well marked. *Voltzia heterophylla* and *Albertia speciosa* are characteristic Bunter species: the Karharbári plant is not specifically identical with the last form, but it appears to be nearly allied. The *Neuropteris* also belongs to a section of the genus with simply pinnate fronds, and this section is characteristic of lower triassic beds in Europe. The *Schizoneura*[3] is said to be near *S. meriani* (*Equisetum meriani*, Bgt.), an upper triassic species. The only other plant which has important affinities with members of the European fossil flora is *Glossozamites stoliczkanus*, belonging to a genus which in European strata ranges from lias to cretaceous.

Gangamopteris angustifolia appears to be identical with a plant described by McCoy[4] from the Newcastle coal-measures in New South Wales (palæozoic) and from beds in Victoria (Australia), the age of

[1] Feistmantel, Rec. G. S. I., IX, pp. 75, 76; X, p. 137.

[2] The plates for the present work had unfortunately been printed before the distinction between the Karharbári group and the Damúda series had been recognised, and consequently the figures of Karharbári plants have been mixed up with those of Damúda species.

[3] *Schizoneura gondwanensis* has been found in the Karharbári field in the uppermost beds (Rec. G. S. I., X, p. 138), but other plants since found in the same beds are Damúda species, and it appears probable that the strata in which *S. gondwanensis* occurs must be classed as Barákar.

[4] Ann. Mag. Nat. Hist., 1847, Ser. 1, XX, p. 148.—Prod. Pal. Victoria, Dec. 2, Pl. XI.

which is not clearly determined, but which are probably lower mesozoic. *Glossopteris communis*, also, is allied to *G. browniana*, one of the characteristic fossils of the carboniferous rocks in New South Wales.

It has already been stated that all the known Tálchir plants are represented in the Karharbári group. On the other hand, there are in the above list only three forms—*Glossopteris communis, Vertebraria indica*, and *Nœggerathia hislopi*—common to the Damúda flora, and all these appear to be much less abundant in the Karharbári group than *Gangamopteris cyclopteroides*. It necessarily follows that, so far as the flora is concerned, the affinities of the Karharbári group to the Tálchir formation are stronger than to the Damúda series, because all the Tálchir plants that can be identified are found in the Karharbári group, whilst only a small percentage of Damúda forms appear to be represented.

Possible representation of group elsewhere.—The discovery that the Karharbári group differs both in mineral character and fossil flora from the lower beds of the Damúda series is so recent that it has not been possible to ascertain whether any representative of the Karharbári beds can be traced at the base of the Barákar, in the Ráníganj and other coal-fields of the Bengal area, but the coal in a seam lying very little above the Tálchir group in the Ráníganj field appears to resemble Karharbári coal in mineral character, and it is far from improbable that further research may shew the present group to have a wider distribution than has hitherto been ascertained.[1]

Damuda series.—The economical importance of the present series has already been noticed. Nearly all the coal-fields of the Indian Peninsula owe their mineral wealth to the presence of Damúda beds, the Kaharbári being the only other important coal-bearing group, and the quantity of valuable minerals contained in the rocks of the present series is probably greater than that known to occur in all the other rock groups of India together. The name Damúda is derived from a river in Western Bengal,[2] on the banks of which some of the richest coal-fields in the country are situated.

Sub-divisions.—The Damúda series has been found to consist in Bengal of three sub-divisions, known in ascending order as Barákar beds, Ironstone shales, and Ráníganj beds. The first and lowest is also found in the Son, Mahánadi, Narbada, and Godávari valleys, the upper subdivisions being represented by groups differing in mineral character from the Bengal beds. In the Sátpúra area the Damúda sub-divisions are known as the Barákar, Motúr, and Bijori groups; and in the Godávari valley, above the Barákar group, there, as in the Sátpúra basin, the only

[1] See foot-note to p. 217.

[2] J. A. S. B. 1856, XXV, p. 253.

coal-bearing formation, a single member of the upper Damúda beds occurs, and is known as the Kámthi group. A similar arrangement prevails in the Mahánadi and Bráhmini area, only two Damúda sub-divisions being found, which appear to correspond to those of the Godávari region.

The mineral characters and geological relations of all these different groups must be described separately: it is sufficient for the purpose at present to note that all consist of sandstones and shales with more or less ferruginous bands, and that some contain coal. Slight unconformity between the different groups has been noticed in places, and the Barákar beds are frequently unconformable to the Tálchirs. The whole thickness of the Damúda series is 8,400 feet in the Ránigauj field, and about 10,000 feet in the Sátpúra basin. It thus constitutes the most important portion of the Gondwána system.

Palæontology.—So far as the examination of the fossils, chiefly plants, obtained from the Damúda series, has progressed hitherto, there appears to be but little difference between the floras of the various groups, several species, including most of the commonest forms, being certainly found both in the upper and lower sub-divisions. It is therefore best to treat the palæontology of the series as a whole, to give a general list of the animals and plants hitherto recognised, which are far from numerous, and to treat of the affinities exhibited by the whole assemblage of forms to the fossil fauna and flora of other countries. The subject, as will be seen, is one of unusual interest and remarkable perplexity.

Taking the series as a whole, the following is a list of the fossils hitherto determined from it,[1] the more common and widely distributed forms being indicated by †.

[1] The following Tálchir, Karharbári, and Damúda fossil plants are figured on Plates III, IV, V, and VI:—

Plate III,	fig.	1.—*Gangamopteris cyclopteroides.*
,,	figs. 2,	3.—*Sphenophyllum speciosum.*
,,	fig.	4.—*Phyllotheca indica* (stem).
,, IV,	fig.	1.—*Schizoneura gondwanensis.*
,,	,,	2.—*Vertebraria indica.*
,,	,,	3.—*Schiz. gondwanensis* (stem).
,, V,	figs. 1, 2,	3.—*Phyllotheca indica.*
,,	fig.	4.—*Glossopteris indica.*
,,	,,	5.—*G. retifera,* Fstm. sp. nov.
,,	,,	6.—*G. angustifolia.*
,, VI,	fig.	1.—*Vertebraria indica.*
,,	,,	2.—*Sphenopteris polymorpha.*
,,	,,	3.—*Macrotæniopteris danæoides.*
,,	,,	4.—*Alethopteris lindleyana.*
,,	,,	5.—*Neuropteris valida.*
,,	,,	6.—*Noeggerathia hislopi.*
,,	,,	7.—*Voltzia heterophylla.*

ANIMALS.

CRUSTACEA—

Estheria mangaliensis.

VERTEBRATA—

Archegosaurus ? (a Labyrinthodont amphibian).
Brachyops laticeps (ditto).

PLANTS.

EQUISETACEÆ—

† *Schizoneura gondwanensis.* Pl. IV, figs. 1, 3.
† *Sphenophyllum speciosum* (*S. trizygia*, Unger). Pl. III, figs. 2, 3.
† *Phyllotheca indica*, and numerous equisetaceous stems. Pl. III, fig. 4; Pl. V, figs, 1, 2, 3.
† *Vertebraria indica* (probably equisetaceous, but of somewhat doubtful nature). Pl. IV, fig. 2; Pl. VI, fig. 1.

FILICES—

Actinopteris bengalensis.
Sphenopteris polymorpha. Pl. VI, fig. 2.
Dicksonia, sp. near *D. concinna.*
† *Alethopteris lindleyana.* Pl. VI, fig. 4.
A. conf. whitbyensis.
A. phegopteroides.
Tæniopteris (*Angiopteridium*), sp.
† *T.* (*Macrotæniopteris*) *danæoides.* Pl. VI, fig. 3.
T. (*M.*) *feddeni.*
Palæovittaria kurzi.
† *Glossopteris browniana.*
† *G. indica* (*G. browniana* var. *indica*, auct.). Pl. V, fig. 4.
† *G. communis.*
G. angustifolia. Pl. V, fig. 6.
G. leptoneura.
G. musæfolia.
G. stricta, and several other species of *Glossopteris.*
G. retifera, Fstm. MS. Pl. V, fig. 5.
Sagenopteris pedunculata (*Glossopteris acaulis.*, McClel.).
S. polyphylla.
Gangamopteris whittiana.
G. hughesi.
Belemnopteris woodmasoniana.

CYCADEACEÆ—

† *Noeggerathia* (*Zamia*) *hislopi.* Pl, VI, fig. 6.
N., sp. near *N. vogesiaca.*
Pterophyllum burdwanense.

CONIFERÆ—

Stems, one of which has been referred with doubt to *Palissya.*

Excluding the forms from the Mángli beds, the only animal fossil hitherto known from the whole series is the *Archegosaurian* from the

Bijori beds of the Sátpúra basin, and as this has not been carefully compared and described, its affinities are somewhat doubtful.

The plant fossils have an unmistakeably mesozoic facies, and are considered by Dr. Feistmantel[1] to represent the Bunter group, the lower sub-division of the European Trias. This view, however, was in a great measure founded upon the relations of the plants found in the Karharbári beds, hitherto classed as Barákars, the only form in the above list which is distinctly triassic being *Schizoneura gondwanensis*, the nearest ally of which is the European *S. paradoxa*, found in the lower trias of the Vosges. Other plants are allied to European upper triassic or rhætic plants, as in the case of the *Actinopteris* and of the *Noeggerathia*, allied to *N. Vogesiaca;* whilst others, again, as *Phyllotheca, Alethopteris lindleyana,* and *Sagenopteris,* have their nearest allies in European beds amongst jurassic forms, *Sagenopteris* being also rhætic. The *Dicksonia* is closely allied to a Siberian oolitic species. *Sphenophyllum,* on the other hand, is a devonian and carboniferous genus, but the Damúda species differs somewhat from the European palæozoic types. *Noeggerathia hislopi* resembles some carboniferous forms almost if not quite as nearly as it does any mesozoic species, whilst the species of *Macrotæniopteris* are related to plants found in various European formations, from permian to jurassic. It is clear, however, that the flora as a whole, so far as it is at present known, has no resemblance to any definite assemblage of plants found in European rocks. The facies is perhaps older mesozoic, but, so far as can be seen, it might be either triassic or jurassic.

The chief peculiarity of the Damúda flora is the abundance of ferns with simple undivided fronds, and especially of the forms with anastomozing venation,—that is, with veins forming a net-work. To this last group belong *Glossopteris, Gangamopteris, Sagenopteris,* and *Belemnopteris,* comprising altogether thirteen species out of the twenty-two ferns, and thirty species of plants altogether, included in the preceding list. When to the thirteen forms already mentioned are added the three species of *Tæniopteris* and one of *Palæovittaria,* having simple fronds and parallel venation, the ferns with undivided leaves will be found to compose more than half the known flora. Nor is this all, for the genus *Glossopteris* especially is remarkable for the abundance of individuals as well as of species, so that it is the characteristic fern-genus of the formation. The simple-leaved ferns are certainly more abundant in mesozoic than in palæozoic rocks in Europe, but still they never prevail to the same extent as in the Damúda series. The only plants, besides ferns, which are of common

[1] Rec. G. S. I., IX, p. 68, &c.; Geol. Mag. 1876, p 491.

occurrence, are *Equisetaceæ*, stems of which, supposed to belong to *Phyllotheca*[1] and *Schizoneura*, are met with in great abundance, whilst *Vertebraria*, which is probably the root of an equisetaceous plant, is as common and characteristic as *Glossopteris*. Cycads and conifers are scarce.

Now, although several forms of the Damúda flora have a mesozoic aspect, the prevalence of ferns and *Equisetaceæ*, and the extremely subordinate share borne by gymnospermous exogens, are palæozoic characters. It would be unreasonable, however, to insist upon this point, because it is impossible to say how far the relative distribution of different classes of plants may have been due to climate. The important point is to call attention to the wide diversity between the composition of the Damúda flora and that found in any European formation.

Relations to carboniferous flora of Australia.—In Australia, however, there is a series of plant-bearing beds[2] which appear closely to resemble those of India in two points, the paucity of marine animal remains throughout the greater portion of the series, and the prevalence in particular beds of the genus *Glossopteris*, associated, as in India, with *Vertebraria* and equisetaceous stems closely resembling some of those found in the Indian coal-fields and referred to the genus *Phyllotheca*. *Gangamopteris* is also met with. The remarkable point is, that some of the commonest plant fossils of the Indian coal-fields, *Glossopteris*, *Phyllotheca*, and *Vertebraria*, are also those most abundantly represented in Australia, and that neither *Glossopteris*, *Gangamopteris*, nor *Vertebraria* has hitherto been found in mesozoic or palæozoic European rocks, whilst *Phyllotheca* is rare, being only known in Europe from the oolites of Italy.[3]

The following is the succession of beds in the coal-fields of New South Wales, where the series appears, so far as it has been described, to be more complete than in other parts of Australia and Tasmania, and where more attention has been devoted to the rocks.

[1] Dr. Feistmantel (Rec. G. S. I. IX, p. 70; J. A. S. B. 1876, pt. 2, p. 347, note, &c., &c.) has referred the greater portion of these stems to *Schizoneura*, but leaves of *Schizoneura* are local, although abundant in certain beds near the top of the Damúda series, whilst the equisetaceous stems are generally distributed. It is not impossible that some, of these fluted stems may belong to other equisetaceous forms besides *Phyllotheca* and *Schizoneura*.

[2] The best general account of the New South Wales coal formations is contained in a paper by the Rev. W. B. Clarke, Q. J. G. S., 1861, p. 354. See also Daintree, Q. J. G. S., 1872, p. 288, &c.; and Clarke, Mines and Mineral Statistics of New South Wales.

[3] A species has recently been described from beds in Siberia, said to be of jurassic Bathonian) age. Heer, Flora fossilis arctica, IV, p. 43, pl IV, f. 1-7. Heer, *l. c.*, consider *Equisetum laterale* from the lower oolites of Yorkshire a species of *Phyllotheca*.

GROUPS.	FOSSILS.
1. Wyanamatta beds	*Pecopteris odontopteroides*, *P. tenuifolia*, *Odontopteris microphylla*; no *Glossopteris* is found.
2. Hawkesbury beds	*Palæoniscus* and several other genera of ganoid fishes with palæozoic affinities.
	N. B.—The plants are found in the Wyanamatta beds, the fish, chiefly, in the Hawkesbury group, but one fish is said to be common to both.
3. Upper coal-measures of Newcastle without marine fossils.	*Pecopteris odontopteroides*, *Alethopteris australis*, *Sphenopteris alata*, and several other species of *Sphenopteris*. *Glossopteris*, several species, especially *G. browniana*, *Phyllotheca*, *Vertebraria*, coniferous plants, *Noeggerathia*,[1] &c. *Urosthenes australis*, a heterocercal-tailed ganoid fish, allied to the carboniferous genus *Pygopterus*.
4. Lower coal-measures with marine fossils.	*Glossopteris browniana*. *Phyllotheca* and *Noeggerathia* are also stated to occur in these beds. *Spirifer*, *Productus*, *Conularia*, *Orthoceras*, *Fenestella*, &c., &c.
	N. B.—The marine fossils, which are typically carboniferous forms, are found in beds overlying and underlying shales and coal with *Glossopteris*, &c.
5. Lower carboniferous or Devonian.	*Lepidodendron nothum*, *Syringodendron dichotomum* (*Cyclostigma kiltorkense*), *Rhacopteris*, *Sphenophyllum*, &c.

Of the carboniferous age of the lower coal-measures, No. 4, there is no question. They are unconformable to the beds No. 5, with a true lower carboniferous flora, but are said to be conformable to the upper coal-measures, No. 3. On the other hand, it is asserted (though not by Australian geologists) that there is a marked distinction between the floras of No. 4 and No. 3, although one species, *Glossopteris browniana*, abounds in both, and, judging from the accounts of all Australian geologists, the genera of plants which prevail in the lower beds, No. 4, are also found in the upper, No. 3. In the same manner No. 1, the Wyanamatta group, is connected with No. 3 by the presence in both of *Pecopteris odontopteroides*, precisely as the Panchet beds in India are connected with the Damúdas by the occurrence in both of the same species of *Schizoneura*, but most of the Wyanamatta plants are distinct from those of the Newcastle coal-beds.

One most important point is the occurrence throughout the upper beds of the New South Wales coal-field of ganoid fishes, belonging to the genera *Palæoniscus*, *Chlithrolepis*, and *Myriolepis*. These are characteristically palæozoic types, although a few allied forms range into the lowest mesozoic rocks. But a selection of fossil fishes from the highest beds of the New South Wales series, the Wyanamatta group or beds immediately underlying it, has been examined by Sir P. Egerton, one of the highest

[1] See foot-note, p. 111.

living authorities, and considered by him to have a permian facies. At the same time, the curious case of the Kota-Maleri beds shews that even remains of fish, characteristic as they usually are, are not conclusive proof of exact age.

The greatest amount of similarity exists between the Damúda beds and the upper or Newcastle coal-measures of New South Wales, No. 3. The latter contain several species of *Glossopteris*, *Alethopteris*, *Sphenopteris*, *Phyllotheca*, *Vertebraria*, and *Noeggerathia*, closely allied to the forms found in the Damúda beds. Hitherto no Damúda plants are known to occur in the Wyanamatta and Hawkesbury beds; on the other hand, the genera of plants said to be found in the lower coal-measures of New South Wales, *Glossopteris*, *Phyllotheca*, and *Noeggerathia*, are also found abundantly in the Damúdas of India, and one species at least—*Glossopteris browniana*—is common to the two; but the other Australian fossils have not hitherto been examined in sufficient detail to enable their relations to be determined with certainty.

This much, however, is certain, that the whole fossil flora of the Australian beds, with the exception of the lower carboniferous or devonian flora No. 5, has just as distinctively a mesozoic facies, when compared with European plant fossils, as has the flora of the Damúdas and other lower Gondwána groups of India, and that the plants of the beds inter-

[1] Q. J. G. S. 1864, XX, p. 1, and Mines and Mineral Statistics, 1875, p. 176. In several papers published by Dr. Feistmantel for the purpose of proving that the Damúda beds are triassic, some of the South Australian plant beds are noticed as clearly mesozoic. None of these beds—not even the asserted jurassic strata of Victoria—are known to be newer than the Wyanamatta group of New South Wales, and the animal remains in the latter are palæozoic. In fact, except the plants, there is little or no evidence to shew that any of the Australian plant-bearing beds, except one group in Queensland, are mesozoic, and many palæontologists are disposed to doubt the value of plant evidence when opposed to the clue to age afforded by animal remains. It is highly probable that some of the upper Australian plant beds are contemporaneous with the lower mesozoic of Europe, and it is almost certain that the Newcastle beds of New South Wales with their equivalents in Tasmania and elsewhere must be classed as palæozoic. This, at least, appears the most probable view, and it has commended itself to some of the best European geologists. To assert, as some writers have done, that various Australian forms of plants—*e. g.*, *Vertebraria* and *Phyllotheca*—are found in typically mesozoic beds, is to beg the question at issue.

The important fact is this: Of the fossils from the upper and lower coal-measures of New South Wales, Nos. 3 and 4 of the above list, which, by the testimony of numerous competent observers, are perfectly conformable and contain a very similar flora, only a few forms are sufficiently known for comparison. Of these few forms a large percentage—certainly more than one-half—are either identical with Damúda species or closely allied. There is no such connection between the flora of the Damúda and that of any European formation whatever. There is, however, a similar connection between the flora of the South African Karoo beds and the plants of both the Damúdas in India and the Newcastle beds in Australia.

stratified with the carboniferous marine fossils have been classed as mesozoic and even as jurassic by eminent palæo-botanists, and this so positively that the observations of the geologists, to whom we are indebted for our knowledge of the Australian rocks, was doubted for years until confirmed by the repeated testimony of several independent observers. On the other hand, the whole fauna of the Australian beds, so far as it is known, from the Wyanamatta beds down, is palæozoic. The curious fact of the intercalation in Australia of beds containing a mesozoic flora with marine strata abounding in carboniferous mollusca serves to show how much caution must be used in forming conclusions as to the age of beds from plant fossils alone, and this argument is especially applicable to the Damúda rocks of India, the flora of which has so remarkable a resemblance to that of the Australian beds.

Another reason for caution in coming to a conclusion from palæobotanical evidence as to the age of the Damúda beds, is to be found in the very remarkable circumstance that whereas their flora agrees best with that found in the upper palæozoic rocks of Australia, the plants found in the underlying Karharbári beds comprise more forms common to the lower triassic flora of Europe than the Damúda beds contain. A somewhat similar anomaly, although on a far smaller scale, is to be seen in the triassic deposits of Central Europe: the St. Cassian beds, containing several representatives of palæozoic generic types, are considered, by the geologists who have described them, newer than the Muschelkalk, in which no palæozoic genera occur. Such anomalies are probably due to the migration of a fauna or flora from one region to another, and to the persistence of peculiar forms in isolated regions.

Relations to Karoo series of South Africa.—Some of the peculiar genera of plant fossils of the Indian coal-fields have also been found in China on the one hand and South Africa on the other, but no detailed descriptions of the rocks in the former country have hitherto been published,[1] whilst the flora of the South African formation is but imperfectly known, and suffers from the same disadvantage as in India, the absence of marine fossils as a guide to its age. Nevertheless, the relations of the South African rocks to the Gondwána series in India are so remarkable that a brief notice of the former is necessary. The probable representation of the Tálchir boulder bed by a breccia apparently of glacial origin at the base of the Karoo beds of South Africa has already been mentioned.

[1] A full account by Baron F. von Richthofen is expected shortly.

The following is the succession[1] of lower secondary strata in Southern Africa, the lowest beds being very probably upper palæozoic :—

UITENHAGE FORMATION—Jurassic.
KAROO SERIES—

1. Stormberg beds: *Glossopteris, Dicynodon*, &c.
2. Beaufort beds: *Glossopteris browniana, G. sutherlandi, Dictyopteris? simplex, Rubidgea mackayi, Phyllotheca*, species of *Dicynodon, Oudenodon, Cynochampsa, Galesaurus*, and numerous other reptiles, a labyrinthodont amphibian, *Micropholis stowii*, and *Palæoniscus*.
3. Koonap beds.
4. Ecca beds: These include the great breccia already noticed. Some plants resembling those in the Beaufort beds are said to occur.

It will be seen that, small as the flora is, it is very similar to that of the Damúda series. One species, *Glossopteris browniana*, is identical, not only with the Indian, but with the Australian form. *G. sutherlandi* is a narrow-leaved species like the Indian and Australian *G. angustifolia* and *Dictyopteris? simplex* appears also to be a *Glossopteris* and resembles some Indian forms. *Rubidgea* is apparently very closely allied to the Damúda *Palæovittaria*. The flora consists of ferns and *Equisetaceæ*. Nor is this all. The Dicynodonts are not represented in the Damúda rocks, but two species are found in the overlying Panchets, and *Micropholis stowii* is a near ally of *Brachiops laticeps* from the Kámthi beds of Mángli.

Lastly, in the Uitenhage formation is found a flora closely resembling that of the upper Gondwána beds, and containing two species apparently identical with Rájmahál plants, and others which are nearly allied. It is a singular fact also that in several parts of Southern Africa, the next formation to the Karoo series in descending order is the almost unfossiliferous "Table Mountain sandstone" which in some respects resembles the upper Vindhyans of India. In other South African localities, however, true carboniferous deposits, with *Lepidodendron, Sigillaria*, &c., underlie the Karoo series unconformably.[2]

It thus appears that the flora of the Damúda series, so far as is at present known, is not represented in Europe by any known fossil flora, although some of the plants are allied to species found in various lower secondary formations. Floras closely agreeing with that preserved in the Damúda beds are, however, met with in Australia and South Africa. On the other hand, the plants of the Karharbári group below the Damúdas, and of the overlying Panchet beds, are much more closely allied to European forms, although several of the associated types of plants in the former, and of animals in the latter, are still

[1] Q. J. G. S., 1867, pp. 140, 167. | [2] Q. J., G. S., 1871, pp. 49, 57, &c.

more nearly allied to Australian or South African genera than to any hitherto discovered in Europe.

Barakar group.—Although there is little difference between the floras found in the various sub-divisions of the Damúda series, the characters and relations of the minor groups require separate notice, and of these groups the lowest and the most important is the Barákar. This group derives its name from a river which traverses the western portion of the Ráníganj coal-field and then falls into the Damúda within the limits of the field.[1] In the higher portion of its course the Barákar river receives the streams which drain the Karharbári coal-field.

Petrology.—The Barákars have an equally extensive range with the Tálchirs, and consist of conglomerates, sandstones of various kinds, shales and coal. The sandstones are often coarse and felspathic, a variety of frequent occurrence being rather massive, white or pale brown in colour, soft at the surface where exposed, and not much harder below, consisting of grains of quartz and *decomposed* felspar. The weathered surface of this sandstone frequently exhibits small projecting knobs, due apparently to calcareous concretions. One of the most striking distinctions between the sandstones of the Tálchirs and those of the overlying formation consists in the felspathic constituents of the former being, as a rule, undecomposed, whilst in the Damúda formation the grains of felspar are almost invariably converted into kaolin.

Besides the whitish felspathic sandstone, another typical Barákar rock is a conglomerate of small, well-rounded, white quartz pebbles. These are sometimes found scattered over the surface and serve to indicate the presence of the conglomerate where it is not exposed in section. The matrix of the conglomerate is usually white sandstone.

It must not be supposed that white is the only colour of the Barákar sandstones. Brown, red, yellow, and other tints are to be found, and in many places predominate. But the whitish felspathic sandstone is a typical rock, preserving its character in localities as far apart as Ráníganj in Bengal and Chánda in the Central Provinces; and although, to the eastward, it is subordinate and forms but a small portion of the group, it appears to be much more largely developed in the Godávari valley.

In general, however, to the eastward, the greater portion of the Barákar rocks consist of shales, grey, blue or black, frequently micaceous, and more or less sandy, occasionally associated with argillaceous iron ore, and often containing seams of coal. Not unfrequently the shaly beds are interstratified with hard flags.

[1] Mem. G. S. I., III, p. 212.

The coals of the Barákar group vary greatly in quality and character in the different coal-fields. They all, however, agree in having a peculiar laminated appearance, due to their being composed of alternating layers of bright and dull coal, the former purer and more bituminous than the latter, which in many cases is shale rather than coal. The best coals are those in which the bright layers predominate, but nearly all seams hitherto discovered are somewhat inferior to average European coal of the carboniferous formation, and there is a general tendency to variation in the thickness and quality of each seam within short distances. At the same time excellent fuel has been obtained from some Barákar seams. Some coal-beds are of immense thickness, single seams (including partings of shale) amounting to as much as 35 feet in the Ràniganj coal-field, 50 feet near Chánda, and no less than 90 feet at Korba in Bilaspúr.[1]

Relations to Talchirs.—In places the Barákars rest quite conformably upon the Tálchirs, and the two groups appear to pass into each other. In general there is an abrupt change in mineral character, but the only case which has hitherto been found in which there is clear evidence of denudation having removed portions of the lower beds during the deposition of the higher group[2] is in the Rámgarh coal-field, where rolled fragments derived from the Tálchirs have been found in the Barákar beds. The Barákars, however, overlap the underlying Tálchirs in many places, and rest upon the metamorphic rocks, and in some coal-fields, as in Ràniganj, the overlap appears to be gradual, the highest beds of the Tálchirs first disappearing, as if they had suffered from denudation. It yet remains to be seen, in the cases in which an apparent passage between the Barákar and Tálchir groups exists, whether representatives of the Karharbári beds do not intervene.

Thickness.—The Barákars appear nowhere to exceed the thickness of 3,300 feet, a development which they attain only, so far as is known, in the Jharia field. In no other field, except Rámgarh, do they exceed 2,000 feet.

There is but little difference in general between the fossil plants of the Barákars and those of the overlying sub-divisions of the Damúdas.

Ironstone shales.—Above the Barákar group in the Ràniganj and a few other fields of the Damúda valley, but nowhere else, there is found a great thickness of black or grey shales,[3] with bands and nodules of clay ironstone (carbonate of iron mixed with clay), some of which is of the carbonaceous variety known as "black band." Towards the base these

[1] The most eastern district of Chhattisgarh, Central Provinces. The locality is about 235 miles east by north from Nágpúr.

[2] Mem. G. S. I., VI, p. (113).

[3] Mem. G. S. I., III, p. 40.

beds become more sandy, and interstratifications of sandstone occur amongst them. The shales disintegrate slowly, and consequently the tract covered by this group is barren and frequently elevated, but the rocks, as a rule, are not well exposed on the surface, although their presence is indicated by fragments of ironstone being scattered about.

The greatest thickness attained by the ironstone shales is about 1,500 feet in the Bokáro coal-field; in the Rániganj field they are nearly as thick. As a rule, they are quite conformable to the underlying Barákars; some slight unconformity which has been observed is very possibly local, but one case[1] has been noticed in which a break in time may be indicated.

Fossils are not common, and, when any occur, they consist usually of *Glossopteris* or *Vertebraria*. Fragments of the stem of a conifer have also been found in these beds, and somewhat resemble a form found in the Kámthi beds of Mángli.

Raniganj group.—The highest group of the Damúda series in the Damúda valley derives its name from the principal town of the mining district of Burdwan,[2] and comprises a great thickness of coarse and fine sandstones with shales and coal seams. The sandstones are, as a rule, moderately coarse, in thick massive beds, white or brown in colour, and obliquely laminated. They are usually more or less felspathic, the felspar being converted into kaolin. Bands of rather calcareous, fine, hard, yellow sandstone are common and characteristic of the group: they often weather out at the surface in nodular fragments. Conglomerates are of rare occurrence. Shales form a much smaller portion of this group than they do (in the Damúda area) of the subjacent Barákars; they are sometimes black and carbonaceous, sometimes bluish-grey, and occasionally red or brown, more or less mixed with sand or stained by iron, and small bands of argillaceous ironstone occasionally occur, though they are not common. The coal is composed of layers, alternately bright and dull, as in the Barákars.

This group is of considerable thickness in the Rániganj field, being, where fully developed, as much as 5,000 feet from top to bottom, and it is possible that this is less than the original thickness, for the next group in ascending order rests upon the denuded surface of the present. The Rániganj group diminishes in thickness in the other fields to the westward, and appears to be represented by groups of different mineral character beyond the limits of the Damúda drainage.

[1] Mem. G. S. I., III, p. 42.

[2] Mem. G. S. I., III, p. 46.

As a general rule, the Ráníganj beds are conformable to the ironstone shales, but in the Bokáro coal-field, near Hazáribágh,[1] the higher group overlaps the lower unconformably and rests upon the Barákars.

No animal remains have been found in the rocks of this formation, but plants are abundant; the majority appear to be the same as those found in the Barákars.

Motur group.—This and the next sub-division are only known to occur in the Sátpúra ranges south of the Narbada valley, where the groups immediately succeeding the Barákars in ascending order have not received the same amount of attention as the rocks of Bengal, the Godávari valley, and Orissa, and the classification proposed for the Sátpúra Gondwánas is only provisional. An immense thickness of beds occurs, probably as much as in the Ráníganj field, but no correct estimate can be formed without further detail.

The Motúr group[2] derives its name from a village of that name situated about twelve miles south-south-east of Pachmari, on the dividing ridge between the valleys of the Denwa (which runs into the Tawa, a tributary of the Narbada) and the Pench (which is a tributary of the Godávari). The village is on the road from Badnúr (Betúl) and Chhindwára to Pachmari, and was at one time used as a sanatarium.

The beds of this group somewhat resemble the Panchets of Bengal in mineral character. They consist of thick, coarse, soft, earthy sandstones, grey and brown, sometimes with red and mottled clays and calcareous nodules. Shales occur, but they are usually sandy and very rarely carbonaceous.

It is probable that the Motúr group is unconformable to the Barákars. No collections of fossils have hitherto been made from the beds of the Motúr horizon.

Bijori group.—The highest members of the Damúda series in the Sátpúra region are exposed in the upper Denwa valley at the southern base of the Mahádeva or Pachmari hills. For the rocks of this horizon the name of Bijori has been proposed,[3] from a small village rendered famous by being the locality whence the only distinctly vertebrate fossil, except *Brachyops*, yet obtained from the Damúda series has been procured.

The rocks of the Bijori horizon are characteristically Damúdas, and comprise shales, occasionally carbonaceous, micaceous flags and sandstones.

Of the relations between the Bijori and Motúr groups nothing definite is known, nor has the thickness of either been determined; 3,000

[1] Mem. G. S. I., VI, p. (100). | [2] Mem. G. S. I., X, p. (131).
[3] Mem. G. S. I., X, p. (129).

to 4,000 feet of beds intervene between the Motúr beds and the base of the Pachmari sandstone, and the greater portion of this thickness may be assigned to the Bijori group.

The most important fossil hitherto found in the Bijori beds is the specimen already referred to, which is the skeleton of an amphibian apparently allied to, if not congeneric with *Archegosaurus*, a carboniferous genus.[1] Plants of the ordinary Damúda types, *Glossopteris*, *Vertebraria*, &c., are found, and *Schizoneura* has also been met with.

Kamthi and Hengir.—Although there is some difference in mineral character between these two groups, the latter, in Chhattisgarh and Western Orissa, appears so closely to represent the beds of the Godávari valley that the two may be united. The name Kámthi is derived from the military station so called,[2] twelve miles north-east of Nágpúr, and the station again derives its name from a village on the opposite side of the Kanhán river, where there is a famous quarry which has yielded a large number of fossils. The term Hengir is derived from a zamindári of that name situated north of Sambalpúr.[3]

The typical Kámthi rocks consist of conglomerates, grits, sandstones, shales and clays. The conglomerates contain pebbles of quartz; the grits are sometimes hard and silicious, so much so as to be quarried for hand-mills (quernstones), but usually they are soft and argillaceous. They are frequently stained by iron, and are often intersected by hard ferruginous bands of a dark-brown colour. The sandstones are of every shade of colour, and vary greatly in character; they comprise fine-grained micaceous beds, white in colour, with blotches and irregular streaks of red, and one of the most characteristic beds of the formation is a very fine argillaceous sandstone, hard, massive, and homogeneous, resembling a shale in structure, except that it exhibits no trace of lamination, yellow in colour below the surface, but becoming red when exposed. It passes into red shale. Another characteristic bed is a hard grey grit or sandstone ringing under the hammer and breaking with a conchoidal fracture. The clays are red or green in colour, and chiefly prevail in the upper portions of the group.

These typical beds, with the exception of the clays, are chiefly developed near Nágpúr; elsewhere the Kámthis consist mainly of soft porous sandstone, brown or white in colour, and conglomeratic in places, often with hard, ferruginous bands, and a few red shales. Here and there, however,

[1] J. A. S. B., XXXIII, 1864, pp. 336, 442.

[2] Rec. G. S. I., 1871, IV, p. 50; Mem. G. S. I., IX, p. (305). The name was formerly written Camptee, and this subsequently assumed the form of Kampti.

[3] Rec. G. S. I., 1875, VIII, p. 112.

a band of one of the characteristic rocks is met with towards the base of the formation.

The chief peculiarity which distinguishes the Kámthi group from the Ráníganj and Bijori groups is the absence of carbonaceous markings. In other Damúda groups, with the exception of the ironstone shales, the remains of plants retain in general a portion of their original carbon, but this appears very rarely to be the case amongst the Kámthis.

The thickness of the Kámthi group has not been determined, but it is undoubtedly considerable, probably 5,000 to 6,000 feet at least.[1] The beds belonging to this group generally appear conformable to the Barákars, but it is extremely doubtful if the conformity be more than apparent, for the Kámthi beds overlap the Barákars in a most irregular manner, and the break in conformity between the two is in places well marked. The Hengir beds, both near Sambalpúr and in the Tálchir coal-field, certainly rest unconformably in places on the Barákar group.[2]

Mangli beds and their fossils.—In the neighbourhood of Mángli,[3] a small deserted village, lying at the northern extremity of the Wardha Gondwána basin, about fifty miles south of Nágpúr and thirty-five north-west of Chánda, some quarries have long existed, from which a very fine red and yellow sandstone, apparently argillaceous, is obtained and employed in building, chiefly for ornamental purposes and for carvings. The stone is precisely similar to that of Silewáda and other typical exposures of the Kámthi group, near Nágpúr, and the coarser associated sandstones of Mángli differ in no way from the ordinary Kámthi grits.

The quarries of Mángli have become well known by name to Indian geologists, and even to those of other countries, from having furnished to Mr. Hislop the first Labyrinthodont amphibian fossil detected in India. They have also yielded a species of *Estheria* and a few plant-remains. The latter are so poor that very little dependance can be placed upon their determination; one is believed to be coniferous, and has been referred to *Palissya*;[4] another is a stem of a fern.

The species of *Estheria* has been named *E. mangaliensis* by Professor Rupert Jones; it is an ally of the European *Estheria minuta*, which is

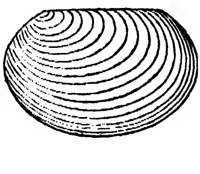
[1] The statement printed in the Rec. G. S. I., X, p. 28, that the Kámthi rocks near Sironcha are 17,000 feet thick, has since been ascertained to be erroneous, the beds being repeated by a fault.

[2] Mem. G. S. I., Vol. I, p. 65; Rec. G. S. I., VIII, p. 113.

[3] This spelling is quite as correct as Mángali, and the latter form is objectionable, since the name has, in consequence, been called and printed Mángáli or even Mangáli. The Mángli beds were discovered by the late Mr. Hislop, Q. J. G. S., XI, pp. 3780.

[4] Feistmantel, Rec. G. S. I., X, p. 26. The identification seems doubtful, for Sir Charles Bunbury suggested the possibility of the same stem belonging to the Lycopodiaceous genus *Knorria*.

a characteristic fossil of the Trias. At the same time *E. mangaliensis* closely resembles a recent species, *E. gihoni*, living in Palestine.[1]



Estheria mangaliensis (enlarged 3 diameters).

The smaller variety of *E. mangaliensis* closely resembles one found in the Panchet group of Bengal, and may be identical; but the Panchet fossil is so poorly preserved that some of the specific characters, depending upon the microscopical texture of the shell, cannot be ascertained, so the identification is not quite certain. The Kámthi plant fossils consist of several forms of *Glossopteris, Gangamopteris, Tæniopteris, Alethopteris*, equisetaceous stems and leaves (*Phyllotheca, Vertebraria*, and *Schizoneura*). None of the Panchet plants except *Schizoneura* have hitherto been detected in the Kámthis. On the evidence of the plants the Kámthi beds have been referred to the Damúda series, and considered equivalent to the Ránigani group. It may, however, be mentioned that all the plants obtained hitherto from the Kámthis are from beds near the base of the group, and some of the upper Kámthi strata may yet be found to represent the Panchets of Bengal. The fossils of the Mángli beds may perhaps indicate that the whole Kámthi group should be referred to a somewhat higher horizon than the Ránigani group. This appears more probable than the idea that the Mángli beds themselves are of later date than the other Kámthi strata, a view held by some palæontologists, but which has been disproved by the geological examination of the country.[2]

[1] Rupert Jones, Pal. Soc., Mon. Foss. Estheriæ, p. 78. The specimens found at Mángli vary in size, and the smaller form is referred by Dr. Feistmantel (Rec. G. S. I., X, p. 26) to *E. minuta*, var. *brodiei*, a rhætic variety of the triassic species. It seems, however, by Professor Rupert Jones to have been described and figured as a small variety of *E. mangaliensis*.—(Q. J. G. S., 1863, p. 149.)

[2] Dr. Feistmantel considers (Rec. G. S. I., X, p. 27) that the fauna and flora of the Mángli beds are newer than those of the Panchets. His principal reason for this view appears to be the discovery by Professor Geinitz of *Estheria mangaliensis*, associated with a rhætic flora, in South America, and a supposed identification of the smaller Mángli *Estheria* with *E. minuta*, var. *brodiei*. The latter identification is apparently a mistake, as already mentioned in a previous note, and the evidence of age, afforded by terrestrial plants and animals in distant regions, is shewn by the Gondwána flora to be not unfrequently conflicting. The evidence afforded by the Mángli plants is of very little value; they are insufficient for accurate determination. At Kawársa, west of Chánda, in beds clearly and unmistakably belonging to the Kámthi group, the same *Estheria mangaliensis* occurs with *Glossopteris browniana, G. indica, Phyllotheca indica*, and *Schizoneura*, the typical Damúda fossils (Mem. G. S. I., XIII, pp. 70, 77), and this occurrence within about 30 miles of Mángli is much more important than the position of the species in South America. The palæontological evidence is thus insufficient to justify the transfer of the Mángli beds to a higher horizon, whilst the geological determination of the position of these beds, which have been carefully

The last, but by far the most important Mángli fossil, is the Labyrinthodont *Brachyops laticeps.*[1] The only allied form found in Europe is *Rhinosaurus jasikovii* from the Russian oolite. Two species belonging to the same group have been described by Professor Huxley,[2] one under the name of *Micropholis stowii* from the Beaufort group of the Karoo series in South Africa, and the other, called *Bothriceps australis,* from an unknown locality in Australia; of these different forms *Micropholis* approaches most nearly in all characters to the Mángli Labyrinthodont.

Head of *Brachyops laticeps*, upper and side views, half natural size.

Panchet group.—The term Panchet was originally applied to two groups of beds in the Ràniganj coal-field.[3] It is now restricted to the lower of these groups, the upper Panchets of the Damúda valley being referred to the upper Gondwána series and ascribed to the Mahádeva formation. The name was derived from an important zamindári (estate) which still comprises a large tract in the southern portion of the Ràniganj coal-field, and formerly included much more; and the same name is that of a large hill, the basal portion of which consists entirely of Panchet beds.

examined, leaves no reasonable doubt that they belong to the Kámthi group. Mr. Hughes (Mem. G. S. I., XIII, p. 71) considers that the position of the Mángli fossiliferous bed is about 600 or 700 feet above the base of the Kámthis, and that the Kawársa beds, which are of similar mineral character, are on nearly the same horizon (*ib.*, p. 75).

[1] Owen, Q. J. G. S., 1855, p. 37.

[2] Q. J. G. S., 1859, p. 642; Rept. Brit. Assoc. 1874, p. 161.

[3] Mem. G. S. I., III, pp. 30, 126, 132, &c.

Petrology.—The great mass of this group consists of thick beds of coarse felspathic and micaceous sandstones, often of a white or greenish-white colour, with bands of red clay from a few inches to 20 feet in thickness. The felspar in the sandstones is occasionally undecomposed, which is never the case in the Damúdas. Conglomeratic beds sometimes occur in the upper portion of the group, but they are not common.

At the base of the group grey and greenish-grey sandstones and shales are usually found in very thin beds, and often highly micaceous. In places the greenish micaceous clays are met with higher in the group.

The Panchet rocks are distinguished from the typical Damúdas by the presence of red clay and the absence of carbonaceous shales, and, as a rule, by the sandstone being much more micaceous. But, as already shewn in the case of the Motúr group, rocks of the Panchet character are found in parts of India interstratified with the Damúdas.

The thickness of the present group in the Damúda valley nowhere exceeds about 1,800 feet. It rests with slight but distinct unconformity upon the denuded surface of the Ràniganj group, the unconformity being most marked in the Bokáro coal-field, and in some places the Panchets completely overlap that group, and rest upon lower helds. Fragments of coal and shale, apparently derived from the Damúdas, have occasionally been found in the conglomerates of the Panchet group.

Palæontology.—The most important remains of animals hitherto found in the lower Gondwána rocks have been derived from the Panchets. In the upper portion of the group there is, in the Rániganj coal-field, a well-marked conglomeratic band containing reptilian and amphibian bones. These are isolated from each other and sometimes slightly rolled. The specimens obtained have been examined and described by Prof. Huxley [1] and comprise the following forms, besides a few others the affinities of which are doubtful :—

AMPHIBIA—
- Labyrinthodontia—
  - *Gonioglyptus longirostris.*
  - *Pachygonia incurvata.*

REPTILIA—
- Dicynodontia—
  - *Dicynodon orientalis.*
- Dinosauria—
  - *Ancistrodon indicus.*

CRUSTACEA—
- *Estheria mangaliensis?*

[1] Pal. Ind. Ser. IV, 1.

The plants hitherto discovered consist of the following species [1] :—

EQUISETACEÆ—

Schizoneura gondwanensis. Pl. VII, fig. 1, 2, 3.

FILICES—

Pecopteris concinna. Pl. VII, fig. 6.
Cyclopteris pachyrhachis. Pl. VII, fig. 5.
Taeniopteris (*Oleandridium*) sp. allied to *O. stenoneuron.* Pl. VII, fig. 4.
Glossopteris, sp. fragments.

Prof. Huxley has pointed out that the reptilian and amphibian remains might be either older mesozoic or upper palæozoic. He says: [2] "So far as an accumulation of uncertainties may go towards forming a conviction, however, I should incline, in view of the whole vertebrate evidence (to which I confine myself) to the opinion that the Indian (*i. e.*, Panchet) fossils are either of triassic age or belong to that fauna which will one day be discovered to fill up the apparent break between the palæozoic and mesozoic forms of life." [3]

Of the plant remains *Pecopteris concinna* and *Cyclopteris pachyrhachis* are known from the rhætic of Europe, and the *Tæniopteris* also is allied to a rhætic species. The genus *Schizoneura* is found in both rhætic and trias; *S. paradoxa*, the form most nearly allied to *S. gondwanensis*, being a characteristic lower triassic fossil (Bunter). The Panchet species is considered by Dr. Feistmantel the same as that found in the beds of the Damúda series, especially in the Rániganj, Bijori, and Kámthi groups.

Pachygonia and *Gonioglyptus* belong to the same section of the *Labyrinthodonts* [4] as *Mastodonsaurus* (trias and rhætic), *Capitosaurus* (trias), and *Trematosaurus* (trias). *Dicynodon* has not been found in Europe, but it abounds in the Beaufort beds, belonging to the Karoo series in Southern Africa, together with the plants already noticed in connection with the Damúda flora. Some of the other reptiles of the Beaufort beds are considered by Prof. Owen to be allied to permian forms, but the rocks have been by other observers either classed as trias or considered as belonging to a period comprising permian and trias, and corresponding to the old "Poikilitic." The balance of evidence, perhaps, is in favour of a triassic age both for the Panchet group of India and the Beaufort beds of South Africa. [5]

[1] Rec. G. S. I., IX, p. 65.

[2] *L. c.*, p. 24.

[3] Subsequently (Q. J. G. S., XXVI, 1870, p. 49) Prof. Huxley expressed an opinion that the Panchets, together with several other reptilian faunas in Europe, Asia, and Africa, were more probably triassic than permian. The definite classification of the Indian beds has, however, been seriously impeded by the discovery that the Maleri *Reptilia*, which have much stronger triassic affinities than the Panchet forms, and which were formerly supposed to occur on the same horizon, belong to much higher beds.

[4] Rept. Brit. Assoc., 1874, pp. 150, 155, 156.

[5] Q. J. G. S., 1867, p. 167; 1870, p. 49; 1876, p. 352.

Almod.—This name is derived from a village at the south base of the Pachmari escarpment in the Sátpúra hills. The rocks consist of sandstones with a few carbonaceous shales. Their relations to the groups above and below require further investigation; no unconformity has hitherto been traced. Their sole importance is derived from their position between the Mahádevas and Damúdas, and to the suggestion that they may represent the Panchet group of Bengal. No fossils have, however, as yet been found in them.

CHAPTER VI.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*.

Upper Gondwána groups—Mahádeva Series—Pachmarhi group—Denwa group—Bágra group—Dubrájpúr group—Rájmahál group—Characters and association of bedded traps—Rájmahál beds in Southern India—Thickness and relations to lower Gondwánas—Area of volcanic action—Palæontology—Relations to Uitenhage flora of South Africa—Relations to Jabalpur and Cutch floras—Ragavapuram shales—Tripetty sandstones—Sripermatur group—Sattavedu group—Trichinopoly or Utatur plant beds—Kota-Maleri group—Palæontology—Jabalpur group—Palæontology—Umia group of Cutch—Narha beds.

Upper Gondwana groups.—The area in which the upper portion of the Gondwána system appears most fully represented, is the Sátpúra basin; and here, although there is evidence of a marked break in the sequence, the division between the upper and lower sub-divisions of the great system is less trenchant than in Bengal. So far as the examination of the Gondwána formations has hitherto proceeded, there appears to be but little connexion between the floras of the upper and lower series, and it is quite possible that several intermediate links remain to be discovered between the Panchet group and the next fossiliferous formation in ascending order, that of Rájmahál. It has already been noticed that the upper Gondwána formations, in each tract in which they occur, differ more from the corresponding rocks in other tracts than the lower Gondwána groups do, and consequently the correlation of the different members of the series is more difficult, and a larger number of small local groups has been instituted. In treating of the upper Gondwána formations, the groups of the Mahádeva series will be first mentioned, then the Rájmaháls and their equivalents; next, the minor groups of the east coast; and, finally, the Kota-Maleri, Jabalpur, and Cutch beds. The general relations between the various groups have already been represented, so far as is practicable, in the table given in the last chapter.

Mahadeva series.—This name was first applied to the sandstone of the Pachmarhi hills,[1] a part of the Sátpúra range south of the Narbada,

[1] J. A. S. B., 1856, XXV, p. 252; Mem. G. S. I., II, pp. 183, 315.

between Hoshangabád and Narsingpúr; these hills are known as Mahádeva or Mahádeo from a cave sacred to Siva, which is the site of a great annual "mêla," or pilgrim fair, in honour of the god. Subsequently the term was extended so as to comprise all the upper beds of the Sátpúra basin, above the Damúdas of the upper Denwa valley, except the Jabalpurs.

The Mahádeva rocks consist chiefly of very thick massive beds of coarse sandstone, grit, and conglomerate. These are frequently ferruginous, or marked with ferruginous bands, as in the Kámthis. They are associated with clays, and occasionally with bands of impure earthy limestone. The sandstones form high ranges of hills, and often weather into vertical scarps of great height, forming conspicuous cliffs in the forest, and contrasting strongly with the black precipices of the Deccan traps and the rounded irregular masses of the more granitoid metamorphic rocks.

In the typical area of the Sátpúra region the Mahádeva rocks attain a thickness of at least 10,000 feet, nine-tenths of which consist of coarse sandstone, grit, and conglomerate. The formation, as a whole, appears to be unconformable to the underlying Damúdas, as it overlaps the upper members of the lower Gondwána series.

Unfortunately the whole of this immense thickness of beds has hitherto yielded scarcely any recognisable fossils. Fragments of wood apparently exogenous, and imperfect remains of stems and leaves, have occasionally been met with, but never hitherto in a state which permitted their characters to be determined.[1] Quite recently a scute of an amphicœlian crocodile has been found in the Denwa valley, and some leaves of *Ptilophyllum* at Lokartalai. The latter are of great importance, but they belong to forms having a wide range in the upper Gondwána strata.

The Mahádeva formation has recently been sub-divided in the Sátpúra region into three groups, the Bágra, Denwa, and Pachmarhi, each of which requires a few remarks.

Pachmarhi group.—The name is derived from Pachmarhi,[2] a village on the top of the hills of the same name, and the site of a sanitarium. The group consists of massive sandstone, whitish or brownish in colour, usually soft, often containing small subangular pebbles, and occasionally intersected by hard ferruginous bands. As a rule, the stratification is

[1] The fossil wood mentioned in the report on the central portion of the Narbada district (Mem. G. S. I., II, p. 190) occurs in beds which have now been shewn to belong to the Jabalpur group and not to the Mahádevas.

[2] Mem. G. S. I., X, p. (155).

obscure, oblique lamination being common, and the different beds of which the group is composed exhibiting great irregularity in superposition and often overlapping each other. The hard ferruginous partings are most irregularly interspersed throughout the mass, usually as thin beds, though not always perfectly parallel to the planes of stratification; sometimes the impregnation with iron is confined to pipes or nodules. Fragments of these ferruginous bands are often scattered in quantities over the surface, and serve to distinguish the outcrop of the Pachmarhi group from those of the underlying beds.[1]

The Pachmarhi group comprises, where thickest, 8,000 feet out of the 10,000 found in the Mahádevas of the Sátpúra hills.

Denwa group.—The middle group of the Sátpúra Mahádevas is named[2] after a stream which rises on the south side of the Pachmarhi range, and turning round the eastern end of the ridge, forms its northern boundary throughout and finally falls into the Tawa. The course of this stream, north of the Pachmarhi hills, is the area of the Denwa rocks, which present a marked contrast to the massive Pachmarhi sandstone, and are principally composed of soft clays, pale greenish-yellow and bright-red mottled with white in colour, forming thick beds interstratified with discontinuous and subordinate bands of white sandstone, and very rare courses of earthy limestone. The sandstones are locally conglomeratic. In short, in mineral character, the Denwa rocks are a repetition of the Motúr group in the middle of the Damúda formation, and resemble the Panchets of Bengal.

The thickness of these beds in the Denwa valley is about 1,200 feet. They appear in places to pass into the underlying group, although in the typical area they are quite distinct.

A fossil reptilian scute, found in the Denwa rocks[3] by Mr. Hughes, appears to have belonged to a crocodile with bi-concave vertebræ, like *Belodon* and *Parasuchus*. The scute in question is very large, and may perhaps have belonged to the last-named genus, which is found in the Kota-Maleri beds. The occurrence is scarcely sufficient to afford much aid in determining the homotaxis of the Denwa beds, but it is interesting, as possibly shewing some connection with the Kota-Maleri group.

At Lokartalai, on the Moran river, close to the western extremity of the Sátpúra basin, some shales and sandstones, having a decidedly Damúda aspect, crop out in an anticlinal from beneath the overlying Bágra beds. These beds even comprise a seam of inferior shaly coal. In mineral

[1] It should not be forgotten that similar ferruginous layers are found in the Kámthis, belonging to the Damúda series.

[2] Mem. G. S. I., X, page (153).

[3] Lydekker, Rec. G. S. I., X, p. 34.

character they closely resemble the Bijori sub-division of the Damúdas, and, until recently, they were classed as lower Gondwánas. Mr. Hughes, however, has now found the two characteristic species of *Ptilophyllum*, *Pt. cutchense* and *Pt. acutifolium*, in these beds, and there can be no hesitation in referring them to the upper Gondwána series : they probably belong to the Denwa group. As the two plants named are found in both the Rájmahál and Cutch groups, the correlation is still imperfect, but the Denwa beds cannot be of much later age than the Rájmahals, as they are separated from the Jabalpur group, itself, if anything, a little anterior in date to the Cutch beds, by the Bágra sub-division of the Mahádevas.

Bagra group.—This name is that of a hill fort[1] built upon the highest sub-division of the Mahádeva formation at the spot where the river Tawa cuts its way through a spur of the Sátpúra hills, south-east of Hoshangabád.

The Bágra group is very largely composed of conglomerate, often coarse, and frequently with a deep red, earthy and sandy matrix. It is more calcareous than any of the other Mahádeva groups, and bands of limestone, sometimes dolomitic, and of calcareous sands and clays, are of frequent occurrence. The limestones are pink or yellowish, whilst clays and sandstones of various colours are interstratified with the conglomerates and limestones. The group is very irregular in composition. The greatest thickness hitherto observed does not exceed 600 to 800 feet. In places the Bágra beds overlap the Denwa group, and rest on the Pachmarhi sandstones.

Dubrajpur group.—The three groups already noticed are only known in the Sátpúra region, although some of them may perhaps hereafter be traced to the eastward. Owing to the paucity of fossil evidence in the Mahádeva series, and to the great difference in mineral character between the upper Gondwána beds of the Central Provinces and those of Bengal, it is impossible to say which groups in the former area are represented in the latter, where the most important group by far is that of Rájmahál.

A thick band of coarse sandstone at the base of the Rájmahál group was at first associated with the overlying beds, but it has since been separated, as it is not conformable to the Rájmahals, and as it is very similar in character to some sandstones of the Damúda valley, formerly described as upper Panchets, but since believed, on evidence which will be noticed in a subsequent chapter relating to the coal-fields of the Damúda valley, to be a probable representative of the lower Mahádevas.

[1] Mem. G. S. I., X, p. (150)

The Dubrájpur group, as this band of sandstones and conglomerates is called, takes its name from a village[1] in the Rájmahál hills, situated about 40 miles north by east of Soory (Suri). The component beds are sandstones of several varieties (grits and conglomerates), for the most part ferruginous. Fine-grained beds are not common, although occasionally shaly sandstones are met with. Most of the coarser beds are ferruginous, and one form of conglomerate, of frequent occurrence, consists of quartz pebbles in a ferruginous matrix. A precisely similar bed is found in the supposed Mahádeva beds of the Damúda valley.

Along the western scarp of the Rájmahál hills, the rocks of the Dubrájpur group rest partly upon the Damúdas and partly upon the metamorphic rocks, the Damúdas (Barákars) being repeatedly overlapped by the Dubrájpur beds in a manner which shews the two to be quite unconformable. The greatest thickness of the Dubrájpur group in the Rájmahál area does not exceed about 450 feet. Some specimens of a cycadaceous plant (*Ptilophyllum*) were once found in the uppermost beds underlying the Rájmahál trap near the southern extremity of the hills; but there is some little doubt as to whether the fossiliferous band may not belong to the Rájmáhal group itself.

Rajmahal group.—This important group derives its name from a range of hills in Bengal,[2] extending north and south from the Ganges to the neighbourhood of Soory (Suri) in Birbhúm. The range again is named from the town of Rájmahál on the Ganges at the northern end of the hills. The representatives of the Rájmahál group, unlike those of other members of the Gondwána series, are confined to the neighbourhood of the eastern coast of the Indian Peninsula. Some species of fossil plants, identical with Rájmahál forms, have been found in other localities, but they are either isolated or associated with plants belonging to a different flora.

Characters and association of bedded traps.—In its typical locality the Rájmahál group consists of a succession of basaltic lava-flows or traps with interstratifications of shale and sandstone. The sedimentary bands are proved to have been deposited in the intervals of time which elapsed between the volcanic outbursts, by the circumstance that the different bands of shale and sandstone differ from each other in mineral character, and also that the upper surface of the shaly beds has sometimes been hardened and altered by the contact of the overlying basalt, whilst the

[1] Pal. Ind., Ser. II, p. 1; Mem. G. S. I., XIII, p. (198).

[2] J. A. S. B., 1854, XXIII, p. 270; Mem. G. S. I., II, p. 313; XIII, p. (209); Pal. Ind., Ser. II, p. 1.

lower surface is never affected. The sedimentary bands are chiefly composed of hard white and grey shale, carbonaceous shale, white and grey sandstone, and hard quartzose grit.

Rajmahal beds in Southern India.—The representatives of the Rájmahál group in other parts of India only comprise volcanic rocks in one locality, on the southern face of the Khási hills overlooking Sylhet in north-eastern Bengal, and in this instance the identification is not perfect, as it depends upon mineral character. There are no sedimentary intertrappean beds, and no fossils have been found. Near the eastern coast, however, representatives of the Rájmahál group have been recognised by their fossil plants in several localities. These representative beds consist of coarse sandstones, often conglomeratic; clays and shales, many of the latter being white and hard, and somewhat resembling the typical intertrappean beds of the Rájmahál area. The sandstones are sometimes richly coloured, red or yellow, but more often grey, white or brown, and they are usually soft and argillaceous. Towards the base of the group a very coarse conglomerate is found, often containing immense blocks of gneiss or other crystalline rocks derived from the immediate neighbourhood.

Such is the general character of the beds; it should, however, be added that there is much variation in the rocks found at the various outcrops which are scattered along the coast at intervals from Cuttack to Trichinopoly, and that, in several cases, distinct zones can be traced, which appear to be of rather later date than the Rájmaháls. Some details of the different outcrops will be given in a subsequent chapter; for the present it is sufficient to point out that the beds of Atgarh near Cuttack[1] and those of Golapilli[2] near Ellore, have the same flora as the Rájmahál group of Bengal; that above the Golapilli beds there are two minor groups, the Ragavapuram shales and the Tripetty sandstones; that these, rather than the true Rájmahál beds, may perhaps be the equivalents of the Sripermatúr and Sattavedu groups near Madras; and that the Trichinopoly or Utatúr plant beds, the flora of which is imperfectly known,[3] may perhaps, like the Sripermatúr beds, be a little higher in position than the Rájmahál group proper. Some beds near Ongole are composed of white hard shales similar to the Ragavapuram beds. The general relations of these

[1] Ball, Rec. G. S. I., X, p. 63; Feistmantel, ib., p. 68.

[2] King, Rec. G. S. I., VII, p. 159; X, p. 56: Feistmantel, Rec. G. S. I., IX, p. 40; Pal. Ind., Ser. II, pt. 3.

[3] Whilst these pages are passing through the press, news has been received of an important discovery of plants in these beds by Mr. Foote.

different minor groups, so far as they have hitherto been determined, is shewn in the following table[1]:—

Bengal.	Orissa.	Ellore.	Ongole.	Near Madras.	Trichinopoly.	Central Provinces.	Cutch.
———	———	Tripetty and Innaparazpolliam.	Sandstones near Guntoor.	———	———	? Chikiala.	Umia.
———	———	———	———	? Sattavedu.	———	Jabalpur	Katrol.
———	———	Ragavapuram.	Plant beds.	Sripermatúr.	Utatúr plant beds.	———	? Chari.
Rájmahál.	Atgarh.	Golapilli.	Sandstones of Budhanada.	———	———	———	———

It should, however, be understood that the distinctions between the groups are not great, and that in several cases the fossil flora has hitherto only been imperfectly examined. A few remarks on the Ragavapuram, Tripetty, Sripermatúr, and Sattavedu sub-divisions will be added after a description of the physical relations and palæontology of the Rájmahál group, as restricted to the beds of Bengal, Orissa, and Ellore.

Thickness and relations to lower Gondwanas.—The bedded basaltic traps of the Rájmahál hills with their associated sedimentary beds attain a thickness of at least 2,000 feet, of which the non-volcanic portion never exceeds in the aggregate 100 feet. The thickness of the beds in Southern India has never been determined. The traps in the typical area rest with general parallelism on the grits and coarse sandstone of the Dubrájpur group, but nevertheless several instances of overlap take place, and in one locality at least there is evidence of the Dubrájpur beds having been denuded before the deposition of the Rájmahál group. In Southern India the Rájmahál beds have been deposited on metamorphic rocks, and appear in general to rest upon a sloping surface, dipping towards the present sea-coast, and having the appearance of an ancient plane of marine denudation.

The great difference of age between the Rájmahál group on the one hand and all the lower Gondwana rocks, including the Damúdas

[1] This differs slightly from several tables by Dr. Feistmantel (*e. g.*, [Pal. Ind., Ser. II, 3, p. 165), who unites the Umia and Katrol groups of Cutch. As, however, only two species of Cephalopoda are known to be common to the two groups, although eleven species are found in the Umia, and no less than twenty-seven in the Katrol beds, it is impossible to consider these groups as identical because a few plants are common to both: see the chapter on the Jurassic series.

and Panchets, on the other, is well illustrated by the change in the flora and by the very much greater amount of disturbance to which the Damúda rocks have been subjected. The Rájmahál traps are almost horizontal, and no faults have been observed in them. As will be shewn in the account of the Ràniganj field, the dykes which abound there are almost certainly of Rájmahál age, and they are newer than the faults of the coal-field.

Area of volcanic action.—From the extent of the area throughout which these dykes are developed, conclusions may be drawn as to the original limits of the volcanic action coincident with the period of deposition of the Rájmahál group. The number of trap dykes gradually diminishes in the coal-fields of the Damúda valley from east to west, until finally in the Karanpura field, south-west of Hazaribágh, volcanic intrusions disappear almost entirely, and none appear to be known further west until basaltic dykes of different age, which apparently are of contemporaneous origin with the much newer Deccan trap (upper cretaceous) make their appearance. Outside of the coal-fields it is difficult to distinguish the dykes belonging to the Rájmahál period from older eruptions, but there is not in Southern Monghyr, Hazaribágh, and Chutia Nágpúr the same abundance of extensive basaltic intrusions as in Birbhúm. So far as can be judged, the region immediately north of the Ràniganj coal-field was one of the foci of eruption, and it is far from improbable that the bedded traps of the Rájmahál hills had originally a considerable extension to the south-west and south, though, as no single outlier has been preserved, it is impossible to feel sure of the inference. There is, however, considerable probability that a large tract in the Damúda valley, including the whole Ràniganj field, may have been once covered with bedded traps.

Palæontology.—The following [1] is a list of the fossil plants hitherto described from this group, including the species found in the Rájmahál

[1] Pal. Ind. Ser. II, Rec. G. S. I., IX, p. 34. On Plates VIII and IX of the present work the following Rájmahál plants are figured:—

Plate VIII, fig. 1.—*Ptilophyllum acutifolium.*
" " 2.—*Pterophyllum rajmahalense.*
" " 3.—*P. princeps.*
" " 4.—*Cycadites confertus.*
" " 5.—*Otozamites bengalensis.*
" " 6.—*Dictyozamites falcatus.*
" " 7.—*Palissya conferta.*
Plate IX, fig. 1.—1*a*.—*Gleichenia bindrabunensis.*
" " 2.—*Alethopteris indica.*
" " 3.—*Pecopteris lobata.*
" " 4.—*Tæniopteris spathulata.*
" " 5.—*T. (Macrotæniopteris) lata.*

hills, and also those from Atgarh and Golapilli. The names in brackets are those by which the species were originally described by Oldham and Morris :—

EQUISETACEÆ—

Equisetum rajmahalense (*Equisetites rajmahalensis*).

FILICES—

Sphenopteris (*Eremopteris*) *hislopi*.
S. (*E.*) *membranosa*.
S. (*Davallioides*) *arguta*.
S. (*Dicksonia*) *bindrabunensis*.
S. (*Hymenophyllites*) *bunburyana*.
Cyclopteris oldhami.
Thinnfeldia salicifolia (*T. indica*, Fstm., *Pecopteris salicifolia*, O. and M.).
Gleichenia bindrabunensis (*Pecopteris* (*Gleichenites*) *gleichenoides*).
Alethopteris indica (*Pecopteris indica*).
Asplenites macrocarpus (*Pecopteris macrocarpa*).
Pecopteris lobata.
Tæniopteris (*Macrotæniopteris*) *ovata* (*T. ovalis*, O. and M. nec. L. and H.).
T. (*M.*) *lata*.
T. (*M.*) *crassinervis*.
T. (*M.*) *morrisi*.
T. (*Angiopteridium*) *macclellandi* (*Stangerites macclellandi*).
T. (*A.*) *spathulata* (*Stangerites spathulata*).
T. (*A.*) *ensis* (*Stangerites ensis*).
Danæopsis rajmahalensis.
Rhizomopteris balli.

CYCADEACEÆ—

Pterophyllum distans.
P. carterianum.
P. crassum.
P. rajmahalense.
P. propinquum ?
P. morrisianum.
P. medlicottianum.
P. princeps.
P. fissum.
Ptilophyllum acutifolium.
P. cutchense.
Otozamites bengalensis (*Palæozamia bengalensis*, O. & M.; *Otozamites abbreviatus*, Fstm.).
O. near *O. brevifolia* (*O. bengalensis*, Schimper).
O. oldhami (*Palæozamia bengalensis var. obtusa*).
Zamites proximus.
Dictyozamites falcatus (*D. indicus*, Fstm.; *Dictyopteris falcata*, O. & M.).
Cycadites rajmahalensis.
C. confertus.
Williamsonia near *W. gigas*.

W. microps.
Cycadinocarpus rajmahalensis.

CONIFERÆ—
Palissya indica (*Taxodites indicus*).
P. conferta (*Cunninghamites confertus*).
Cunninghamites dubiosus (*C. inæquifolius*, O. and M.).
Chirolepis gracilis (*Araucarites gracilis*).
C. sp. near *C. muensteri.*
Araucarites macropterus.
Echinostrobus indicus (*E. rajmahalensis*,[1] Fstm., *Arthrotaxites indicus*, O. and M.).

By far the greater part of the Rájmahál fossils have been obtained from two bands of fine-grained whitish or greyish shales—the upper 25 to 30 feet thick, the lower 10 to 15—separated from each other by a lava flow, and having other beds of trap with intercalations of sandstone and shale above and below.

The first thing which must strike any one in looking over the above list is the great change in forms of life between the upper and lower Gondwána series, so far as we are yet acquainted with them. It is highly probable that intermediate beds may hereafter be found, but for the present there seems to be just as great a break in the flora as there is, in Bengal at least, in the stratigraphy. The most striking distinction is that the prevalent forms in the lower Gondwánas are *Equisetaceæ* and ferns of the *Glossopteris* type, *Cycadeaceæ* being rare, whilst in the upper Gondwánas, and especially in the Rájmahál group, *Cycadeaceæ* prevail, their individual abundance being so great that they frequently form the mass of the vegetation. In fact, the Cycads, and especially *Ptilophyllum acutifolium*, are just as abundant and characteristic in the Rájmahál group as *Glossopteris* and *Vertebraria* are in the Damúdas.

Only a single species is found in the Rájmahál group, and also in European strata. This is *Sphenopteris arguta*, found also in the lower oolite of Yorkshire. The specimen referred to *Pterophyllum propinquum* is too fragmentary for certain identification, and the identity of the *Sphenopteris* is by no means free from doubt. Several forms, however, are considered by the various palæontologists who have described them to be allied to European lias and rhætic plants, and a decided opinion has been expressed by Dr. Feistmantel that the Rájmahál group is of liassic age. This conclusion may possibly be correct, but it is on the whole premature, and it is scarcely supported by the evidence. There is certainly not so strong a connection between the Rájmahál and the typical European liassic flora as there is between the Cutch flora and that of the

[1] No sufficient reason has been assigned for the alteration of the original specific name in the case of this species and of the Dictyozamites, nor does it appear desirable that the later term *indica* should replace the much older name *salicifolia* in the case of the *Thinnfeldia*.

English lower oolites, and yet it appears probable that the homotaxis in the latter case is misleading to a certain extent, and that the beds are really upper jurassic. Besides, taking Dr. Feistmantel's own data,[1] no fewer than fifteen of the above species are allied to rhætic species, whilst only three have a close connection with liassic plants, two of these having equally close rhætic relations. It is true that the European liassic flora is poorer than the rhætic, but not in this proportion. On the other hand, six species exhibit affinities with lower oolitic forms. It has also been pointed out by Dr. Oldham[2] that there is a decided connection between some Rájmahál plants and species belonging to the Wealden flora of Europe. Two of the Rájmahál plants, *viz.*, *Gleichenia bindrabunensis* and *Danæopsis rajmahalensis*, are near species found in the upper trias, (Keuper,) most fossil forms of *Gleichenia* being, however, cretaceous, whilst *Macrotæniopteris lata* is quite as nearly allied to the permian *M. abnormis* as to any of the mesozoic forms, and some of the species of *Pterophyllum* also have permian affinities. *Cyclopteris oldhami*,

[1] Pal. Ind., Ser. II, pp. 143, 187. The Rájmahál plants allied to rhætic European forms are said by Dr. Feistmantel to be—

Indian species.		European species.
Equisetum rajmahalense	allied to	*E. muensteri.*
Thinnfeldia salicifolia	,,	*T. decurrens.*
Alethopteris indica	,,	*Asplenites rosserti.*
Asplenites macrocarpus	,,	*A. ottonis.*
Gleichenia bindrabunensis	,,	*Gleichenites microphyllus.*
Tæniopteris macclellandi	,,	*T. muensteri.*
Macrotæniopteris lata	,,	*T. gigantea.*
Pterophyllum distans	,,	*P. (Ctenophyllum) braunianum.*
P. princeps	,,	*P. braunsi.*
P. fissum	,,	*P. comptum* and *P. minus.*
P. near *P. propinquum*	,,	*P. propinquum.*
Otozamites near *O. brevifolia*	,,	*O. brevifolia.*
Palissya indica	,,	*P. brauni.*
Chirolepis gracilis	,,	*C. muensteri.*
C. sp. near *C. muensteri*	,,	,,

The forms with liassic affinities are—

Equisetum rajmahalense	,,	*E. liasinum.*
Tæniopteris macclellandi	,,	*T. muensteri.*
Cycadites rajmahalensis	,,	*C. linearis.*

Whilst oolitic relations are shewn by—

Sphenopteris arguta, a lower oolitic species.

Hymenophyllites bunburyanus	allied to	*Tympanophora racemosa.*
Alethopteris indica	,,	*A. whitbyensis.*
Pterophyllum fissum	,,	*P. minus*, a rhætic species also.
Williamsonia sp. near *W. gigas*	,,	*W. gigas.*
Araucarites macropterus	,,	*A. brodiei.*

[2] Mem. G. S. I., II, p. 321.

Sphenopteris membranosa and *S. hislopi* are also most nearly connected with Palæozoic forms. Taking the whole evidence, it appears that the Rájmahál flora has no very marked connection with any single European group, and although the facies does not differ so widely from that of all European fossil floras as in the case of the Damúda series, it is only possible to indicate the relative position by an approximation. Generally, the Rájmahál flora is most nearly allied to rhætic and lower oolite, but it is by no means improbable that India in Rájmahál times was separated from the land then existing in the European area and that the two belonged to distinct botanical regions, since, out of about fifty species, only one can be identified with a European fossil plant.

Relations to Uitenhage flora of South Africa.—Again, however, as in the case of the Damúda series, we have some indications of a connection with South Africa. The resemblance of the South African Karoo flora to that found in the Damuda rocks has already been noticed. Above the Karoo beds there is found another great series known by the name of Uitenhage,[1] the upper portion of which consists of several groups containing marine fossils, and ranging in age from lower to upper jurassic, the uppermost beds having some neocomian forms mixed with the jurassic species; whilst beneath all the marine beds, immediately above the Enon conglomerate at the base of the series, there is found in one locality, Geelhoutboom on Sundays river, Uitenhage, a set of plant-bearing beds, the flora of which presents some affinities to that of the Rájmahál group. The following is a list of the plants described, with their allies in the Rájmahál flora:—

FILICES.

Pecopteris atherstonei. } Allied to the Rájmahál species *Alethopteris*
P. rubidgei. } *indica.*
P. africana.
Asplenites lobata, identical with the Rájmahál species, *Pecopteris lobata.*
Sphenopteris antipodum.
Cyclopteris jenkinsiana, allied to *C. oldhami.*

CYCADEACEÆ.

Palæozamia (*Otozamites*) *recta.*
P. (*Podozamites*) *morrisi.*
P. rubidgei.
P. (*v. Pterophyllum*) *africana.*

CONIFERÆ.

Arthrotaxites, sp. allied to *Echinostrobus indicus.*

[1] Tate and Rupert Jones, Q. J. G. S., 1867, pp. 144, 149, &c.: Stow, Q. J. G. S., 1871, p. 497.

The alliances between the Cycads are vague. *Palæozamia rubidgei* has some slight resemblance to *Pterophyllum distans,* and *P. africana,* if it be a *Pterophyllum,* may be allied to *P. morrisianum,* but the connection is not close. The Cycads indeed appear more nearly related to some lower oolitic European forms. The *Pecopteris lobata* appears however to be the commonest plant of the formation, and *Cyclopteris jenkinsiana* is also found in abundance.

Relations to Jabalpur and Cutch floras.—Owing to the prevalence of the same species of *Ptilophyllum* in both, and to a general resemblance in the flora, it was long supposed that the Jabalpur group and the plant-bearing beds of Cutch (Kachh) were the equivalents of the Rájmahál group. A more careful examination of the plants has shewn that there are important differences between the floras of the different localities, and, judging by the facies of each flora, Dr. Feistmantel has come to the conclusion that the Rájmahál group is older than the other two. It must be borne in mind that the Rájmahâls have never been found in contact with either of the other groups,[1] and that the view of their relative ages is based upon the relations of their fossil floras to the plants found in European rocks. Still the circumstance that, near Cocanada, beds occur containing marine fossils, identical with those of strata which are associated with the Cutch plant-beds, and that these fossiliferous bands have been identified, on apparently good evidence, with some strata which are found, near Ellore, overlying a formation with Rájmahál fossils, tends strongly to confirm Dr. Feistmantel's views.

Ragavapuram shales.—Upon the Golapilli beds in the neighbourhood of Ellore[2] there is found resting a thin band of white and buff shales having a few interstratifications of sandstones towards the base. No unconformity has been detected between these shales and the Golapilli sandstones, but there appears to be some difference in the flora, for, whereas the plants found in the Golapilli sandstones are, without exception, either Rájmahál forms or else species peculiar to the beds, the former being far more numerous than the latter, the flora of the overlying shales comprises a few species allied to Jabalpur plants in addition to several forms common to the beds below. The shales have been called Ragavapuram, from a village situated about 26 miles

[1] The case of the Kota-Maleri beds will be found mentioned below. The supposed identification of the Rájmahál group in the Godávari valley, near Sironcha, appears to have been based on insufficient evidence.

[2] King, Rec. G. S. I., X., p. 56; Feistmantel, Pal. Ind., Ser. III, 3, p. 163.

north-north-east of Ellore. The plants found comprise the following species[1] :—

Tæniopteris (Angiopteridium) spathulata.
T. (Angiopteridium), sp.
Ptilophyllum cutchense.
P. acutifolium.
Pterophyllum, sp.
Taxites, sp.
Gingko crassipes.

The two last are allied to Jabalpur forms. With the plants are some marine shells, chiefly casts; amongst these are some *Ammonites* apparently allied to middle jurassic species, the principal form being near *A. opis*, but distinguished by having the ribs simple throughout. *A. opis* belongs to the subgenus *Stephanoceras* and to the group of *A. macrocephalus*, and is found in the Chari and Katrol beds of Cutch (Callovian and Oxfordian). Besides the ammonites, *Leda*, *Pecten*, *Gervillia*, &c., occur, the *Leda* being especially common and characteristic.

The Ragavapuram shales cannot be more than 100 feet thick, and they are overlapped at both ends by Tripetty sandstones. They closely resemble some shales found further down the coast near Ongole and containing a similar flora, and they appear to represent the Sripermatúr group near Madras.

Tripetty sandstones.—Above the shales just noticed there is another thin band of dark brown and red sandstones and conglomerates, chiefly ferruginous, with silicious and argillaceous bands and beds of concretionary clay ironstone. Towards the bottom these sandstones become softer and less ferruginous. In the main area, near Ellore, the Tripetty beds are only 40 feet thick. They are named from a pagoda called Chinna (little) Tripetty, which stands upon a scarp composed of them, about 20 miles north-north-west of Ellore.

The Tripetty beds, in the main area, have only yielded fossil wood, but from some outlying patches supposed to belong to the same band near Innaparazpolliam, about 24 miles north by east of Cocanada, Mr. King obtained two *Trigoniæ*,—*T. smeei* and *T. ventricosa*,—both of which are characteristic of the Umia beds of Cutch. *T. ventricosa* is also very abundant in some upper jurassic beds, forming the uppermost group of the Uitenhage series in South Africa.

The sequence of upper Gondwána beds in the neighbourhood of Ellore is very instructive. The whole series rests unconformably on the Kámthis (lower Gondwána), and although the whole thickness of the upper Gondwána series is trifling, apparently not exceeding 200 or 300

[1] In the list given in Pal. Ind., Ser. II, 3, p. 3 165, both Ragavapuram and Sripermatúr forms were included.

feet, it comprises representatives of the Rájmahál and Umia groups, and of an intermediate formation. It is evident that these beds must represent between them a considerable period of geological time, for it is scarcely probable that the Rájmahál beds can be much newer than lower jurassic (Bathonian), and it is certain that the Tripetty beds, if they are the equivalents of the Umia group, must be at the top of the jurassic series, whilst the intermediate Ragavapuram shales are perhaps, judging from their *Ammonites*, on about the same horizon as the Chári beds of Cutch (Oxfordian or Callovian). Yet these thin bands exhibit no marked unconformity. The middle group is overlapped at both ends, it is true, but there is no sign of any important break. It is clear that the country must have undergone very little disturbance in the interval between the deposition of the different groups; and judging from this instance, it is impossible to argue from the small amount of discordance between successive sub-divisions of the Gondwána series, that the period of time which elapsed between the different groups was of small amount. But for the fossils, no notice would, in all probability, have been taken of the distinctions between the different beds at Ellore, and many similar sub-divisions might be made in such groups as the Kámthi or Pachmarhi if the strata were fossiliferous.

Sripermatur group.—As already mentioned, the upper Gondwána beds near Madras are divided into two groups,[1] the lower of which has been named from Sripermatúr, a town about 25 miles west-south-west of Madras, and a well-known locality for fossil plants. This group is partly composed of white shales containing plants, and associated with sandstones, grits, and micaceous sandy shales. Conglomerates occur, especially towards the base, where they are coarse and occasionally contain boulders of great size, but all conglomeratic beds in this group are of loose texture and not compact.

It is in the Sripermatúr shales that the fossils of this formation are found. They consist of both animals (marine shells) and plants, the two being found in the same beds. The shells, however, are ill-preserved, and have not been determined. They comprise two or three species of *Ammonites* and several lamellibranchiate bivalves, amongst which forms of *Aucella* are particularly common.[2]

[1] Foote, Mem. G. S. I., X, p. 64.

[2] In the Ongole plant beds, considered to be on the same approximate horizon as the Sripermatúr shales, the caudal portion of a crustacean has been found, which belongs to the genus *Eryon*, and appears to have some resemblance to the liassic species *E. Barrovensis*; Feistmantel, Rec. G. S. I., X, p. 193, figs. 1, 2, 3. A comparison of these figures with that of *E. Barrovensis*, Q. J. G. S., 1866, p. 495, Pl. XXV, fig. 1, will shew, however, that there are some important differences between the two forms. In the paper quoted, the locality of the fossil was, by mistake, said to be Sripermatúr.

a list of the plants as determined by Dr. Feistmantel, the species common to the Jabalpur group being marked with an asterisk (*), whilst those found in the Rájmahál group are thus indicated (†) :—

FILICES.

* *Alethopteris whitbyensis.*	† *Tæniopteris (Angiopteridium) spathulata.*
† *A. indica.*	*Thinnfeldia*, sp.

CYCADEACEÆ.

* † *Ptilophyllum cutchense.*	*Otozamites*, 2 species undescribed.
* † *P. acutifolium.*	*Pterophyllum*, 2 sp. undescribed.
† *Dictyozamites falcatus.*	*Cycadites*, sp.
* *Otozamites hislopi.*	*Cycadolepis*, sp.
O., sp. allied to *O. tenuatus.*	

CONIFERÆ.

* † *Palissya indica.*	*Taxites*, sp., found also in the Ragavapuram shales.
† *P. conferta.*	*Pachyphyllum*, sp., allied to *P. peregrinum.*
* *Echinostrobus expansus.*	
* *Araucarites cutchensis.*	

Judging from the above list the Sripermatúr beds appear to be of rather later age than the Rájmahál and Golapilli group, and, like the Ragavapuram shales, to be intermediate between those formations and the Jabalpur group.

Sattavedu group.—The upper group receives its name from the Sattavedu hills, a series of moderately elevated ridges lying on the border of the North Arcot and Madras districts, about 35 miles north-west of Madras. The rocks consist of immense beds of coarse, compact conglomerate, with sandstones and grits intercalated. The conglomerates are chiefly composed, in the typical locality, of quartzite pebbles in a hard cement, sometimes argillaceous and ferruginous, sometimes calcareous and silicious. In other areas, the pebbles are of granite, syenite, and quartz. The conglomerates are several hundreds of feet in thickness.

The junction of the group with the Sripermatúr beds is ill seen, but the two appear to be conformable. Only imperfect plant-remains have been obtained from the Sattavedu group; the best preserved appears to be a *Dictyozamites.* It is probable that this group is only the upper portion of the Sripermatúr beds.

Trichinopoly or Utatur plant-beds.—Beneath the cretaceous rocks, near Trichinopoly, there are found,[1] cropping out along the western ridge of the cretaceous area, and resting upon metamorphic rocks, several small patches of soft shales and sandstones with a coarse conglomerate, containing large rounded masses of gneiss, at the base. The shales are, as a rule, micaceous and sandy; in places they abound in impressions of

[1] H. F. Blanford, Mem. G. S. I., IV, p. 39.

leaves, chiefly of *Ptilophyllum*, but these markings are frequently ill-preserved, and from the friable nature of the rocks, specimens are very difficult to transport without obliteration. Owing to the softness of the material, the impressions originally obtained have perished, but they were said to comprise *Ptilophyllum acutifolium, P. cutchense, Gleichenia bindrabunensis*, and one of the species of *Tæniopteris* found in the Rájmahál group.

Kota-Maleri group.—The rocks of the Gondwána series in the Pránhita and Godávari valley south of Chánda are still imperfectly known, but two names of localities have been familiar to Indian geologists for many years on account of the discoveries of fossil fish by Dr. Walker and Dr. Bell,[1] and of fish teeth and reptilian bones by Mr. Hislop.[2] The former were discovered at a small village called Kota, on the left bank of the Pránhita or Wainganga, about 8 miles above its junction with the Godávari; the latter were procured at Maledi or Maleri, a village situated 32 miles north-west of Sironcha, about 21 miles west of the Pránhita, and 30 miles north of the Godávari.

The rocks of the Kota-Maleri group are somewhat similar in character to those of the Panchets of Bengal. The most distinctive beds are red and green clays with soft white or greenish argillaceous sandstones. There is, however, an entire absence of the yellowish-green micaceous sandstones and shales, so characteristic of the Panchets. With the clays of the Kota-Maleri groups are associated flaggy beds of somewhat earthy grey limestone, and thick sandstones of various colours, usually containing small nodules of green clay. Clays are less abundant in the upper portion of the group, which consists chiefly of coarse and loosely compacted sandstone, varying in colour, and containing fragments of pink and buff shale arranged in bands. Similar bands of shale fragments in sandstone are found at a lower horizon, but they are more common above the clays forming the lower part of the group.

The limestones contain fossil fish at Kota, whilst reptilian remains (*Hyperodapedon* and *Parasuchus*) and *Ceratodus* teeth, abound in some places in the clays, and *Estheriæ* and portions of insects have been found in the shaly beds associated with the limestones. Nothing definite has hitherto been ascertained of the thickness of this group. It rests unconformably on the Kámthis, and for a long time it was supposed that the Maleri beds represented the Panchets of Bengal, whilst the limestones of Kota were considered to be of later date on account of their containing liassic forms of fish. The discovery, however, in the Maleri beds, of plant-

[1] Q. J. G. S., 1851, p. 272; 1852, p. 230; 1853, p. 351; 1854, p. 371.
[2] Mem. G. S. I., I, p. 295; Q. J. G. S., 1864, p. 280, &c.

remains identical with those of the Rájmahál and Jabalpur groups has rendered it evident that the former must be transferred to the upper Gondwána series, and it has also been shewn that the Kota limestones are intercalated in the clays and sandstones of the Maleri beds, although these limestones are above the *Ceratodus* and *Hyperodapedon* strata of Maleri itself.[1] Remains of *Hyperodapedon* have, however, been found in clays, precisely similar to those of Maleri, and apparently at a much higher horizon than the Kota limestones.

This alteration of the views formerly held as to the relations of the Kota-Maleri beds is supported to some extent by stratigraphical characters. Mr. King separates from the Kota-Maleri beds an overlying group which he calls "Chikiala sandstones," from the village of Chikiala on the Pránhita, 15 miles north of Sironcha. These upper sandstones comprise vitreous ferruginous conglomerates, hard silicious and argillaceous conglomerates, and bands of concretionary clay ironstones, all having a marked resemblance to the beds of Tripetty, near Ellore; and Mr. King suggests that the two formations are identical. At the base of the typical Kota-Maleri beds also, in the neighbourhood of Sironcha, are some sandstones which it has been thought may represent the Golapilli (Rájmahál) group, but upon this point further evidence is desirable, there being no stratigraphical characters of importance to support the conclusion. The palæontological evidence will be mentioned presently.

Palæontology.—The following is a list of the fossils hitherto procured:—

ANIMALS.

CRUSTACEA.

Estheria kotahensis.	*Candona kotahensis.*

INSECTA.

Undetermined.

PISCES.

Lepidotus deccanensis.	*Tetragonolepis analis.*
L. longiceps.	*T. rugosus.*
L. breviceps.	*Dapedius egertoni.*
L. pachylepis,	*Ceratodus hunterianus.*
L. calcaratus.	*C. hislopianus.*
Tetragonolepis oldhami.	*C. virapa.*

[1] Hughes, Mem. G. S. I., XIII, p. 81; King, Rec. G. S. I., X, p. 61. Both geologists agree in classing together the Kota and Maleri beds. Several details are from MS. reports by the geologists mentioned.

REPTILIA.

Hyperodapedon, sp. | *Parasuchus*, sp.

PLANTS.

FILICES.

Tæniopteris (Angiopteridium), sp. The species found also in the Ragavapuram shales.

CYCADEACEÆ.

Ptilophyllum acutifolium. | *Cycadites*, sp.

CONIFERÆ.

Palissya conferta. | *Chirolepis*, sp. near *C. muensteri*.
P. jabalpurensis. | *Araucarites cutchensis*.

A few fragmentary impressions of bivalve shells have also been found. They are not sufficiently perfect to enable the genus to be determined, and it is uncertain whether they are fresh-water or not, but probably they are. They may belong to the *Unionidæ*.

Despite the very imperfect examination which these rocks have hitherto received, they have already yielded more genera of animals than any other Gondwána groups, more even than the Panchets. The question of homotaxis has consequently been much discussed, and a few remarks on it are necessary here.

Anterior extremity of right upper jaw of *Hyperodapedon* from Mángli. Natural size.

The genus *Parasuchus*[1] belongs to a typically mesozoic group of crocodiles with biconcave vertebræ. It is placed by Professor Huxley in the same section of this family with the European genera *Belodon* and *Stagonolepis*, which are almost confined to triassic rocks in Europe, some remains of *Belodon* having also been found in rhætic beds.

The genus *Hyperodapedon*[2] belongs to a peculiar group of lizard-like Saurians, considered by some naturalists to form a distinct order, equivalent to the snakes or lizards, and known as *Rhynchocephala*,[3]

[1] This genus does not appear to have been described, but it has been so frequently referred to in the Survey publications that it is scarcely possible to treat the name as a merely manuscript designation, liable to be changed at any time. See Q. J. G. S., 1875, XXXI, p. 427.

[2] Huxley, Q. J. G. S., 1869, p. 138.

[3] Günther, Phil. Trans., 1867, CLVII, p. 626.

but classed by others as a sub-division of the *Lacertilia*. This group is represented in the living fauna only by two species of *Hatteria* found in islands near New Zealand. *Hyperodapedon* has hitherto been found in Europe only in triassic rocks.

The fish are all characteristically mesozoic. The genus *Lepidotus* ranges from the lias to the lower chalk, the Kota species being considered by Sir P. Egerton, who described them, as showing liassic or oolitic

Right palatal tooth of *Ceratodus hislopianus* from Mángli. Natural size.

affinities. *Tetragonolepis* is only known from liassic beds; *Dapedius* also is liassic. *Ceratodus*, on the other hand, is, in Europe, chiefly found in triassic rocks, in which the genus is rather extensively distributed.[1] Some forms have, however, been found in rhætic beds, and one in the Stonesfield slate (lower oolitic). Recently the same genus has been discovered living in Australia.

Neither the *Estheria* nor the *Candona* can be considered as very characteristic of age.[2] The former belongs to the same group as *E. minuta*, so abundant in the triassic and rhætic beds of Europe, but represented by closely allied forms in various rocks from the carboniferous to the present day. The genus *Candona* has a similar range, and there is nothing distinctive in the Kota species.

The insects have not been examined, and it only remains to notice the plants. These have chiefly been obtained from localities in the neighbourhood of Jangáon, south-west of Sirpur, and some reptilian remains, identical with those of Maleri, were found in clays associated with the plant beds. The two species of plants first discovered by Mr. Hughes in these beds near Jangáon were *Palissya jabalpurensis* and *Araucarites*

[1] For descriptions and figures of the species of *Lepidotus*, *Tetragonolepis*, and *Dapedius*, by Sir P. Egerton, see Q. J. G. S., 1851, p. 272; 1854, p. 371; and Pal. Ind., Ser. 4, Pt. 2. The *Ceratodi* are described by Mr. Miall in the publication last named and (originally) by Dr. Oldham; Mem. G. S. I., I., p. 295.

[2] T. R. Jones, Mon. Foss. Estheriæ, p. 78: Q. J. G. S., 1863, p. 149.

cutchensis, and as these are both Jabalpur forms, it was supposed[1] that the Kota-Maleri beds represented the Jabalpur group. At the same time *Palissya conferta* and a *Chirolepis* very close to *C. muensteri* were obtained by Mr. King at Anáram, on the right bank of the Pranhita, from sandstones underlying the fish beds of Kota on the left bank. The same two species had been found by Mr. Fedden in 1873 near Jangáon, and as both these forms occur in the Rájmahál beds at Golapilli, whilst neither is found in the Jabalpur or Cutch groups, it was inferred that the sandstone at the base of the Kota-Maleri group—the Sironcha sandstones of Mr. King's classification—should be classed as Rájmahals. *Palissya conferta*, or a form undistinguishable from it, has, however, since been obtained by Mr. Hughes in undoubted Kota-Maleri beds, associated with a *Tæniopteris* and some other plants, found also in the Ragavapuram shales, and *Palissya conferta* itself has been detected in the Sripermatúr group. Several species of plants are, moreover, common to the Rájmahál and Kach-Jabalpur groups; the typical flora of the first has hitherto never been found in Central India, but is restricted to a series of beds confined to the east coast, and it would, therefore, be premature to identify the sandstones, near Sironcha and Jangáon, containing *Palissya conferta* and *Chirolepis*, with the Rájmahals of Eastern India, even if it were certain that these sandstones were inferior in position to the Maleri clays.

Quite recently, the discovery of *Ptilophyllum*, the characteristic genus of the upper Gondwána series, in the Kota-Maleri beds, has confirmed the idea first suggested by the conifers, that this group must be classed as upper Gondwána.

It will be seen that the evidence as to age is conflicting, so long as these beds are compared with the fauna and flora of European formations. Some of the animal remains point to a triassic epoch; others have liassic affinities, whilst the plants have a jurassic or rhætic facies. On the other hand, *Ceratodus* and *Hyperodapedon*, characteristically triassic types in Europe, are allied to animals still living in Australia or New Zealand. The Kota-Maleri beds, indeed, serve as a warning against placing too much reliance upon the affinities of fossil terrestrial faunas and floras with those of Europe, in estimating age or even homotaxis. Until the plant-remains of the Kota-Maleri group were discovered, the Maleri beds were classed with the Panchets, partly on account of their mineral character, but more because they appeared to be connected by homotaxis with the same European formation, the trias, of which the Panchet group was considered to be representative. The Kota rocks, also,

[1] Rec. G. S. I., IX, pp. 132-35.

on account of their fauna, were considered higher and assigned to a liassic horizon. The relations of these beds to European formations have only been rendered more obscure by the discovery of the plants contained in them, but as several of those plants are common to the Jabalpur and Rájmahál groups, which are well developed at no great distance, it appears best to refer the Kota-Maleri beds to the same approximate horizon as the Ragavapuram and Sripermatúr groups, leaving it for future research to determine how far exact equivalents of the Rájmahál, Sripermatúr, and Jabalpur sub-divisions may or may not be distinguished in the strata classed together as Kota-Maleri.

Jabalpur group.—In the first account of the central portion of the Narbada valley,[1] a group of rocks was distinguished as "upper Damúda." It was, however, pointed out at the time that this group was not only unconformable to the "lower Damúda," but that it contained a very different flora. When, subsequently, a true upper Damúda group was found in the Rániganj coal-field, it became desirable to distinguish the Narbada beds by a different name, and as they are well developed in the immediate vicinity of Jabalpur, they have been named from that town.

The Jabalpur group consists of clays, shales, and earthy sandstones with some thin beds of coal. The clays and soft shales, which are the most characteristic beds of the formation, are pale-coloured, usually white, pale lavender-grey, or pale red. The sandstones are generally coarse and conglomeratic. Carbonaceous shales are met with in several places, and, occasionally, one or more thin bands of jet-coal, very different in character from the coal of the Damúda formation. Limestone is rare. At the base of the formation, when resting upon gneissic rocks, there is frequently found a coarse, compact sandstone, so hard and compact as almost to resemble a quartzite. It is often conglomeratic, and the matrix containing the pebbles consists of white earthy rock in a porcellanic condition. Occasionally, but rarely, this bed is calcareous.

The thickness of the Jabalpur formation does not appear to have been determined with any accuracy. It is, however, of no great vertical extent, and, so far as is known, it nowhere exceeds 1,000 feet. The relations of the Jabalpur group to the underlying Mahádevas have not been examined in detail, but there appears to be conformity in general between the two.

[1] J. G. Medlicott, Mem. G. S. I., II, p. 176. The Jabalpur formation was at this time not clearly distinguished in places from the Mahádevas. The former was supposed to be the lower; in reality the Jabalpur formation is not only newer than the Mahádeva, but it appears to be the latest member of the whole Gondwána series, and to contain several plants found also in the Umia group of Cutch. Further accounts of the Jabalpur group will be found in Rec. G. S. I., IV, p. 75; and Mem. G. S. I., X, p. (142).

Palæontology.—The following is a list of the fossils found in this formation,[1] those found also in the Umia beds of Cutch being marked with an asterisk thus (*); whilst those also met with in the Rájmahál group are distinguished by a (†):—

FILICES.

† *Sphenopteris*, sp. allied to *S. arguta*.
Dicksonia, sp.
Alethopteris medlicottiana.
* *A. whitbyensis*.
A. lobifolia.
Tæniopteris (*Macrotæniopteris*) *satpurensis*.
Glossopteris, sp. (fragments only).
Sagenopteris, sp.

CYCADEACEÆ.

Pterophyllum nerbuddaicum.
*† *Ptilophyllum cutchense*.
*† *P. acutifolium*.
Podozamites lanceolatus.
P. spathulatus.
P. hacketi.
Otozamites hislopi.
O. gracilis.
O. distans.
O. angustatus.
† *Williamsonia*, near *W. gigas*.
Cycadites allied to *C. gramineus*.

CONIFERÆ.

*† *Palissya indica*.
P. jabalpurensis.
* *Araucarites cutchensis*.
* *Echinostrobus expansus*.
E. rhombicus.
Brachyphyllum mammillare.
Taxites tenerrimus.
Gingko lobata (*Cylopteris* or *Baiera lobata*).
Phœnicopsis.
Czekanowskia.

The following species, according to Dr. Feistmantel, are either found in the lower jurassic beds of England, or represented by very closely allied species:—

Sphenopteris arguta.
Alethopteris whitbyensis.
A. lobifolia.
Podozamites lanceolatus.
Williamsonia, near *W. gigas*.
Brachyphyllum mammillare.
Echinostrobus expansus.
Araucarites cutchensis, near *A. phillipsi*.
Gingko lobata near *G. (Cyclopteris) digitata*.

whilst one species, *Otozamites gracilis*, is liassic. *Alethopteris whitbyensis* and *Podozamites lanceolatus* are also found in several localities in Western and Northern Asia, and in Eastern Siberia they are associated with *Cycadites gramineus*, *Czekanowskia*, *Phœnicopsis*, and some other plants nearly allied to Jabalpur species.

[1] As determined by Dr. Feistmantel. See Rec. G. S. I., 1876, IX, p. 125; Pal. Ind. XI, 2. The following are figured on plate X:—

Figure 1. *Alethopteris medlicottiana*.
„ 2. *Otozamites gracilis*.
„ 3. *O. hislopi*.
Figures 4 & 5. *Podozamites lanceolatus*.
Figures 6 & 7. *Brachyphyllum mammillare*.
Figure 8. *Palissya jabalpurensis*.
„ 9. *P. indica*.
Figures 10 & 11. *Araucarites cutchensis*.

It will be seen that there are nearly as many Rájmahál as Umia species found in the Jabalpur group, so far as the flora has hitherto been determined. It should, however, be remembered that the known species of the Rájmahál flora are nearly fifty in number, while those of the Umia flora are much less numerous (about twenty-two[1]), five of the former and six of the latter being found in the Jabalpur beds, which are distinguished by a conspicuous want of many of the commonest and most characteristic Rájmahál plants, such as the broad-leaved species of *Pterophyllum.*

It must also be borne in mind that there is a marked connection between the Jabalpur and Cutch beds in the considerable proportion of species in both common to the lower oolitic rocks of England. *Sphenopteris arguta*, one of the plants common to the Rájmaháls and Jabalpur, but hitherto not found in the Umia beds of Cutch,[2] is also a lower oolitic species. But too great stress must not be laid on identifications of Indian fossil plants with European, as a guide to age.

On the whole, the Jabalpur beds are probably on nearly the same horizon as the Umia beds of Cutch, but possibly represent a period intermediate between the Cutch and Rájmahál groups, though nearer to the former. At the same time the circumstance that no representative of the Jabalpur flora has yet been found on the east coast of the Indian Peninsula, whilst the Rájmahál flora is confined to the neighbourhood of the east coast, suggests that the distinction may be due to the beds having been formed in regions with a different flora. But bearing in mind the large amount of evidence which exists to shew that the greater part, if not the whole, of India proper was a land area in Gondwána times, this idea of the country having been divided into distinct botanical regions is less probable than the theory of a difference in age between the Rájmahál and Jabalpur groups.

Umia group of Cutch (Kachh).—This group is only mentioned here because of its relations to the uppermost beds of the Gondwána series. The name Umia is derived from a village about 50 miles north-west of Bhúj, the chief town of Cutch. The group will receive a fuller description under the head of the jurassic formations, and an account will be given of its mineral character and fossil animals.

The especial interest of this group in connection with those just enumerated is due to the fact that, in Cutch, beds containing plants, several of which are identical with those of the Jabalpur beds, are interstratified with rocks yielding marine fossils.

[1] Dr. Feistmantel enumerates twenty-eight in his Memoir, but some are varieties only, others stems not identified generically.

[2] It is, however, found in Cutch at a lower horizon.

The following is a list of the plants from the Umia beds [1] :—

ALGÆ.

? *Chondrites dichotomus.*—Perhaps founded on a badly perserved coniferous stem.

FILICES.

* *Tæniopteris (Oleandridium) vittata.*	* *Pachypteris specifica.*
T. densinervis.	*P. brevipinnata.*
* *Alethopteris whitbyensis.*	*Actinopteris*, sp.
Pecopteris tenera.	

CYCADEACEÆ.

† *Ptilophyllum cutchense.*	* *Otozamites* near *O. goldiæi.*
† *P. acutifolium.*	* *Cycadites cutchensis.*
P. brachyphyllum.	* *Williamsonia blanfordi.*
Otozamites contiguus.	*Cycadolepis pilosa.*
* *O. imbricatus.*	

CONIFERÆ.

Palissya bhoojoorensis.	* *Pachyphyllum divaricatum.*
† *P. indica.*	* *Echinostrobus expansus.*
* *P.* near *P. laxa.*	* *Araucarites cutchensis.*

Those marked thus (*) are represented by the same or closely allied forms in the lower oolitic beds of Europe, being chiefly found in Yorkshire. Four of the species marked are considered identical with European lower oolitic forms, *viz.*, *Tæniopteris vittata*, *Pecopteris whitbyensis*, *Pachyphyllum divaricatum*, and *Echinostrobus expansus*, the other six being closely allied.

Species thus marked (†) occur also in the Rájmahál group. The forms common to the Jabalpur beds have already been mentioned.

The homotaxis of the Umia flora is thus shewn to be lower oolitic, yet these beds, as will be explained more fully when treating of the jurassic rocks of Cutch, rest upon strata with marine fossils, amongst which are *Cephalopoda* and some other mollusca with upper oolitic (Portland and Tithonian) affinities, and are immediately overlaid by a bed containing neocomian *Ammonites* and *Crioceras*.

Narha beds.—At a somewhat lower horizon in the rocks of Cutch, a few plants have been found near a village named Narha, in the northern part of the province,[2] in beds interstratified with the Katrol group, the *Cephalopoda* of which are considered by Dr. Waagen as corresponding to

[1] Pal. Ind. Ser. XI, 1; Rec. G. S. I., IX, p. 29. The following Umia species are figured on Plate XI :—

Figure 1.	*Tæniopteris vittata.*	Figure 5.	*Echinostrobus expansus.*
„ 2.	*Alethopteris whitbyensis.*	„ 6.	*Pachyphyllum divaricatum.*
Figures 3 & 4.	*Ptilophyllum cutchense.*	Figures 7 & 8.	*Araucarites cutchensis.*

[2] Mem. G. S. I., IX, p. 213; Pal. Ind., Ser. XI, 1, p. 80.

those of the Kimmeridge and Upper Oxford beds of Europe. These plants consist of the following species :—

Sphenopteris cf. *arguta.*	*Otozamites* cf. *contiguus.*
Alethopteris whitbyensis.	*Araucarites cutchensis.*

The three last are apparently identical with species found in the Umia beds, whilst *Sphenopteris arguta* is an English lower oolitic species, found also in the Jabalpur and Rájmahál groups. The *Alethopteris* and *Araucarites* are also Jabalpur forms. This evidence, so far as it goes, tends to shew a great persistency in the flora, and it may indicate that the Jabalpur beds are a little older than the Umia group, since the connection of the flora found in the Katrol beds of Narha with that of the Jabalpur group is quite as strong as with the Umia plant fossils.

CHAPTER VII.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF COAL-FIELDS, ETC.

Distribution of Gondwána basins — Relations to existing river valleys — Groups of basins — Origin of different groups of basins — I, RÁJMAHÁL REGION — Tálchirs — Damúdas — Distribution of Damúdas and Dubrájpur group — Rájmahál group — II, BIRBHÚM, DEOGARH, and KARHARBÁRI REGION — A, Small basins of Birbhúm, Deogarh, etc. — Tangsuli — Kundit Karayah — Sahajori — Jainti or Karaun — B, Small basins of North-Eastern Hazáribágh — Karharbári, etc.

Distribution of Gondwana basins.—The general distribution of Gondwána basins in India has already been described, but in proceeding to give further details of the separate areas in which these rocks are found, it is convenient to divide the scattered tracts into groups and sub-groups. To a certain extent this grouping is simple and natural, there being in some cases several Gondwána basins at no great distance from each other, in all of which the same sub-divisions of the series are represented. A typical case occurs in the Damúda valley. But still there is frequently much difficulty in assigning definite limits to the several groups, since most of them tend to pass into each other where the basins of one group approach those of another.

Relations to existing river valleys.—If the view which, as previously mentioned, is held by some Indian geologists, be correct, and the beds of the Gondwána series were originally deposited in river basins [1] closely approximating to those of the streams which now drain the country, it ought to be simple to group the existing representatives of the series according to the river valleys in which they occur. But a glance at the map will shew that the largest and geologically most important Gondwána area known—that of the Sátpúra region—is situated partly in the drainage of the Narbada, partly in that of the Godávari, whilst there is considerable probability that the Gondwána beds are continuous beneath the covering of Deccan traps with those of the South Rewah [2]

[1] Rec. G. S. I., 1870, Vol. III, p. 5.

[2] It is as well to call attention here to the circumstance that the volcanic outbursts of the Deccan trap must have obliterated all pre-existing valleys, and consequently if the direction and area of the present river valleys correspond in any way with those of pre-trappean times, it can only be by accident.

and Sohágpur field, which forms in places the watershed between the Son, a tributary of the Ganges, and the affluents of the Máhánadi, and extends for some distance into the valleys of both rivers. In this case, therefore, some other guide to the principle on which the different basins should be grouped must be detected. If the Gondwána series, as all Indian geologists believe, are fluviatile deposits, either the whole were accumulated in one great system of river valleys or in several detached drainage areas. The extent of country over which the Gondwána rocks are known to occur is not by any means too great for these beds to have been deposited by one river. The whole area scarcely exceeds the present alluvial plain of the Ganges, which is only a river of the second magnitude, and all might be easily comprised within the deposits of such streams as the Mississipi or Obi. It is probable that if the Gondwánas were accumulated in different river basins, there would be a well-marked petrological distinction between the corresponding groups from top to bottom; if all the beds were deposited in one great basin, there might still be distinctions in places due to the different forms of the detritus derived from the pre-existing rocks in various parts of the area, and probably to unequal changes of level, but there would be a tendency to a passage between the beds in different parts of the country.

Groups of basins.—It has been already pointed out that the characters of the Tálchirs and Barákar groups are similar throughout the Gondwána area, and that these groups are almost everywhere found at the base of the series, the few exceptions which occur being mostly in the case of small and detached outliers. So far, therefore, the evidence is strongly in favour of all the Gondwána areas having been deposited in one river valley or system of river valleys. It is the groups above the Barákars, the upper portion of the lower Gondwánas, and the whole of the upper Gondwána series, which vary in the different regions. Partly by means of these higher rocks, and partly by geographical position, we may classify the different basins of the Peninsula as follows:—

I.—Rájmahál region.
II.—Birbhúm (Beerbhoom), Deogarh (Deogurh), and Karharbári region.
III.—Damúda (Damoodur) valley region.
IV.—Son (Soane), Máhánadi, and Bráhmani valleys.
V.—Sátpúra region.
VI.—Godávari valley.
VII.—East Coast region.

The eastern regions, Nos. I and VII, consist of one or two upper Gondwána groups either isolated or resting on some member of the lower Gondwánas. In the Rájmahál hills the upper Gondwánas rest upon the

Barákars, near Ellore on the Kámthis. In the Birbhúm basins only the lowest groups, the Tálchirs and Barákars, are found, but in the Damúda valley there is a magnificent series of lower Gondwána beds, with only a few small outliers of the upper portion of the series, and even these outliers are imperfectly identified. In the Sátpúra basin there appears to be a full representation of the whole series, whilst both in the Máhánadi and in the Godávari valley there is a break above the Barákars, although the upper portion of the lower Gondwána series is represented, and in the Godávari, at all events, some of the upper Gondwána groups are largely developed.

Origin of different groups of basins.—These differences may be due to the circumstance that the main system of river valleys in which the Tálchirs and Barákars were deposited was broken up at the end of the Barákar period, and whilst in some tracts, as in the Damúda valley and Sátpúra hills, beds continued to be deposited, in others denudation may have taken place. The eruption of the Rájmahál traps was probably marked by much disturbance, and they appear to have closed the Gondwána period in Bengal, although higher deposits are found to the west and south. The marked difference between the formations resting upon the Barákar group in the Damúda and Máhánadi valleys respectively may point to the elevation of the Chutia Nágpúr highland at a period immediately subsequent to the close of the Barákar epoch, and the rise, though gentle at first and insufficient to produce much disturbance in the lowest Gondwána groups, may have been accelerated subsequently, and have culminated before the period of the Rájmahál outbursts, thus coinciding in time with the main faults of the Damúda valley coal-fields. It is true that no outliers of the Gondwána series have hitherto been discovered on the Chutia Nágpúr highland, and that on the eastern flanks of the plateau the Tálchirs, and occasionally the Barákars also, are found exposed in valleys in a manner which suggests that the lower Gondwána beds occupy the hollows in which they were originally deposited. There is, however, some remarkable evidence in support of the view that high outliers formerly existed, and the occurrence of lower Gondwána rocks in hollows by no means precludes the idea of great changes of level having occurred since the deposition of these beds, since, as already pointed out, the soft Gondwána beds would wear more rapidly than the harder metamorphic rocks on which they rest, and hence the old surface inequalities would have a tendency to be repeated.

One of the highest hills in the western part of the Chutia Nágpúr table-land is that of Mailan Pát, in Eastern Sirgúja.[1] The

[1] All these details are from manuscript notes.

upper part of this hill, which has a flat top, presents the following section :—

		Feet.
1.	Laterite, about	100
2.	Deccan trap	150
3.	Sandstone, calcareous above	50
4.	Gneiss	—

The sandstone No. 3, which is referred to the Lameta group (cretaceous), contains in abundance pebbles apparently derived from the lower Gondwána series, and probably from either Barákars or Panchets. So little disturbance has affected the region since Lameta times that it appears more reasonable to infer that these pebbles were derived from beds then existing at a higher level on the Chutia Nágpúr highland than to suppose that the Lameta beds and overlying trap have been raised to their present elevation by a local movement in which the whole neighbouring country did not participate.

There are several examples in the same neighbourhood of lower Gondwána beds apparently raised to considerable elevations. One is the occurrence of Barákar and Tálchir beds at Chopé on the Hazáribágh plateau; a second, the occurrence of sandstones, probably, to judge from their mineral characters, of Barákar age, capping Madaghir hill, 2,500 feet high, about 5 miles north of the northern scarp of the Chutia Nágpúr table-land, and 3 miles west of the Karanpura coal-field; and a third, the existence of outlying masses of Damúda sandstones on the high gneiss hills of Mahtin and Pindura, west of the Chutia Nágpur table-land, on the ridge of hilly ground separating the basins of the Son and Máhánadi rivers.

The preservation of so complete a series of rocks in the Sátpura region is doubtless due to the protective covering of the Deccan trap, and the same preservative agency may have been the cause of so large an area of soft sandstones still remaining in the Godávari drainage and in the upper valley of the Son. In the same manner the traps of the Rájmahál hills have doubtless prevented the removal by denudation of the Barákars exposed on the flanks of the range, and it is quite possible that to the former extension of the same traps to the west and southwest we owe the existence, at the present day, of the valuable coal-fields in the Damúda and Barákar valleys. If this view be correct, and the preservation of the existing Gondwána basins be due to local protective causes, it is probable that the members of the series formerly covered an enormous area, and that by far the greater portion has been removed by denudation. At the same time, this view is by no means generally accepted by Indian geologists, and the opposite opinion, that the original area of

the Gondwána basins differed but little from that now remaining, is held by good observers, who have carefully studied the formations in the field; and it is remarkable, if the Gondwána beds formerly occupied a wide area, that outliers are not more abundant. The outliers which exist are mostly of Tálchir and Barákar rocks—a circumstance which rather favours the view above suggested that these groups were more extensively distributed than later sub-divisions of the system.

I.—Rájmahál region.—It appears best to describe the Rájmahál Gondwána area apart from all others. The upper Gondwána beds are identified by their flora with some of those found in the outcrops along the east coast of the peninsula; but the interstratification of these beds with basaltic lava flows is peculiar to the present tract. The lower Gondwána beds of the Rájmahál hills may have been connected with those of the basins in Birbhúm and the Damúda valley.

1.—Rajmahal Hills.—A range of flat-topped hills with a general direction from north to south, and chiefly composed of basaltic rocks, extends from the Ganges below Colgong to the neighbourhood of Soory in Birbhúm. These hills are usually called the Rájmahál hills from the town of Rájmahál on the Ganges close to their north-eastern corner, whilst the tract of country including them is generally known as the Dáman-i-koh.[1]

To the west of the range lies the great undulating area of metamorphic rocks included in the districts of Bhagalpur and Birbhúm, broken only by occasional isolated peaks; to the east is the alluvium of the Gangetic plain. The River Ganges runs round the northern extremity of the range, and for some distance close to its eastern edge, whilst the original or loop-line of the East Indian Railway skirts the eastern and northern margin of the hill country throughout.

The Rájmahál hills are almost flat-topped; but the plateaus by which they are capped have, in general, a low dip to the eastward, corresponding to the prevailing dip of the rocks. This dip disappears in the northern portion of the hills. The plateaus are extensive, and are inhabited and cultivated. The range is drained and divided by three streams, all of which traverse it from west to east; the Gumáni to the north, running north-east through the Chuparbhita Pass to join the Morel or Morang, which runs nearly from north to south within the hills; the Bansloi, which runs through the Pachwára Pass; and the Bráhmani, which separates the hills of the Dáman-i-koh from the southern portion of the range known as the Rámghar hills.

[1] Foot of the hills. This name was originally applied to the tracts at the western base of the range.

The Gondwána rocks [1] occurring in this tract consist of the following formations:—

	Approximate thickness in feet.
Rájmahál group (chiefly volcanic)	1,500
Dubrájpur group (Mahádeva ?)	450
Barákar	500
Tálchir	?

As already mentioned, the whole of the beds in the southern part of the area dip from west to east, and the hard basaltic lava-flows form scarps to the westward, and dip away gradually to the eastward until the whole of the rocks disappear beneath the alluvium of the Ganges valley. In the northern part of the hill tract the rocks appear to be nearly horizontal. To the south the western boundary of the sedimentary beds, inferior to the traps, is a line of fault running from north by west to south by east. Further to the north these sedimentary beds rest directly upon the metamorphic rocks. The beds beneath the traps are chiefly exposed along the western boundary and in the valleys of some of the streams which traverse the hills: only one instance is known of the appearance of sandstones to the east of the hills. By far the greater portion of the area is entirely composed of basaltic traps, whilst a large tract on the hill-tops is covered with a thick accumulation of laterite.

Talchirs.—The Tálchir formation is very poorly represented in the Rájmahál area, the few tracts of it which are found being apparently only small portions which have escaped denudation. In no other area in Bengal is there so much appearance of irregular overlap of this formation by the Barákar group. The principal localities at which Tálchirs have been detected on the western side of the Rájmahál hills are in several places a few miles east of the small civil station of Godda, one of the patches occupying about 5 square miles of country. There are also two little inliers, one of them surrounded by traps, about 8 to 10 miles further north-north-east, and another small inlier some 20 miles to the south. None of the tracts presents any peculiarities; the beds seen are the usual greenish silts and sandstones, and the boulders so commonly associated with the formation have only been found in the Narganjo tract south of Godda. There is, however, a boulder bed, which may be of Tálchir age, at the base of the Damúda formation on the Bráhmani river, and in one or two other places in the same position.

Damudas.—The Damúda rocks occur also in isolated tracts, separated from each other by larger areas, throughout which higher strata (Dubrájpur

[1] For a complete account by Mr. Ball, see Mem. G. S. I., XIII, pp. (155)-(248).

beds or Rájmaháls) rest directly upon the metamorphics. The principal of these tracts of Damúda rocks beginning from the north are—

1. The Hura coal-field, a tract about 15 miles from north to south at the north-western edge of the hills near Manhiari. This tract commences about 13 miles south-east of Colgong, and lies for the most part outside the range of hills and on the edge of the Gangetic alluvium.

2. The Chuparbhita coal-field at the western end of the gorge through the hills cut by the Gumáni stream, and known as the Chuparbhita Pass. This tract commences about 10 miles south of the last, and is of irregular form, the rocks being partly exposed to the west of the basaltic trap ranges, partly in valleys excavated in the overlying trap. The greatest length is about 8 miles.

3. The Pachwára field, similarly situated to the last, at the western end of the gorge cut by the Bansloi and known as the Pachwára Pass. A considerable area of the Damúda rocks is here exposed, extending about 7 miles from east to west and 6 from north to south.

4. A strip of country about 8 miles long on the western flank of the hills, commencing near Mahuagarhi hill, 5 or 6 miles south of the Pachwára area, and only separated by about 2 miles from the next tract to the southward. With this tract several inliers to the eastward within the range are connected, the latter exposures being surrounded by Dubrájpur beds or trap. The strip west of the hills is traversed by a stream tributary to the Bráhmani called the Gúmra; the principal inlier within the ranges is near a village called Gopikándar.

5. The Bráhmani coal-field, which extends for about 10 miles along the valley of the river from which it is named.

Besides these larger exposures of Damúda rocks, some smaller areas occur, which are for the most part of minor importance. One of these is found at Pathárgháta, about 6 miles below Colgong on the Ganges. Here are a few isolated hills surrounded by the alluvium, and composed of white sandstones and clays resting upon gneiss and capped by trap. One or two isolated outcrops intervene between this locality and the larger exposure to the south-east. Another small patch of Damúda rocks is found at Pir Pahár, 5 or 6 miles north-west of Rájmahál, where several small hills of coarse sandstone occur surrounded by alluvium.[1]

In all the tracts named, except those near Manhiari and Colgong, the Damúda beds are of the usual Barákar characters, and consist of alternations of grit, sandstone, and shale, with occasional beds of inferior coal.

[1] This has been suggested as a suitable locality for boring for coal, and an attempt has been made to explore the rocks, but hitherto without success.

All the coal seams hitherto found in the Rájmahál area are poor and shaly, though many of them are of considerable thickness and can furnish a large quantity of inferior fuel. In the Hura tract the Damúda beds are similar to those of Pathárgháta, and consist of friable felspathic grits, (the felspar decomposed,) and soft white shales with a few thick seams of inferior coal. It has been suggested by Mr. Ball that these beds may belong to a higher horizon, as they present some resemblance to the Rániganj group of the Damúda coal-fields.

The Damúda beds are in many places disturbed and faulted, so as to contrast strongly with the Mahádevas and Rájmaháls resting upon them. The unconformity is well marked and unmistakable, and there appears every reason for supposing that the coal-bearing rocks had in this area been upheaved and denuded until only isolated basins were left, before the deposition of the overlying Dubrájpur grits.

Distribution of Damudas and Dubrajpur beds.—The distribution of these latter beds is most peculiar, and in order to explain it and at the same time to give a few further details of the Damúdas, it is as well briefly to describe the sedimentary beds intervening between the traps and the metamorphic formations on the west flank of the Rájmahál hills, beginning from the north. South of Manhiari, the Damúdas of the Hura field are found to be only 60 or 70 feet thick, resting upon the gneiss and capped by trap with inter-trappean layers, the Damúda beds being the white argillaceous shales and sandstones, as at Pathárgháta. A few miles to the southward these latter beds become thicker and more carbonaceous, and contain seams of inferior coal. They, however, thin out again further south, and just before they disappear, beds of the Dubrájpur group come in below the traps. A few miles farther south, near a small Santhál village called Simaldhap, the trap rests directly on the metamorphic rocks. There are but two other instances of these two formations being in contact; one is about 12 miles further south, the other a short distance to the eastward, within the Chuparbhita Pass. The trap near Simaldhap rests upon the gneiss for about a mile, when the Dubrájpur group of rocks again comes in between the two. This Dubrájpur group has already been described in the last chapter, it differs widely in character from the Damúdas, and consists of coarse grits and conglomerates, often ferruginous, containing quartz and gneiss pebbles, with occasionally hard and dark ferruginous bands.

At the Chuparbhita Pass the Damúda rocks come in again beneath the Dubrájpur beds and run up the lateral valleys: the character of the Damúdas, here and to the southward, is more that of typical Barákars. For some miles to the north-east on the sides of the pass, the Dubrájpur grits intervene below the traps, but at length they thin

out, and the volcanic rocks rest directly on the Barákars. South of the Gumáni valley the Barákars disappear once more on the western flank of the hills, and only the Dubrájpur beds occur between the traps and the metamorphic rocks; the former recur, however, to the south in the Bansloi valley (Pachwára Pass), and here also, as at the Chuparbhita Pass, the Dubrájpur rocks are only found at the western end of the valley and disappear to the eastward, where the traps rest directly upon the Damúdas. Again, south of the Bansloi, the Dubrájpur beds alone appear, about 250 feet thick, beneath Mahuagarhi hill, but only for a few miles, for the Barákar rocks come in again south of the hill, and extend thence southward, with only one break of about 2 miles, to the Bráhmani, the Dubrájpur grits resting upon them throughout. South of the Bráhmani valley only the Dubrájpur beds are met with along the edge of the hills, but as the boundary is a fault, Damúdas mayexist beneath the surface. Both in the Bráhmani valley and in several isolated patches of Damúda rocks within the hill area to the north, as at the Chuparbhita and Pachwára Passes, the Dubrájpur beds disappear to the eastward, and the traps rest upon the Barákars, so that throughout the whole area the former are evidently confined to a narrow strip of country along the western edge of the hill tract. There is clear evidence in the Bráhmani valley and elsewhere that considerable denudation of the Dubrájpur beds took place before the commencement of the volcanic epoch, and there is reason for believing that the disappearance of these beds to the eastward is due to their having been removed before the lava flows commenced.

Rajmahal group.—The following general section of the Rájmahál group occurs in the northern part of the hills. The thicknesses, in the case of the volcanic rocks especially, are mere approximations, the beds varying greatly in this respect :—

		Feet.
1.	Basalt, in flows of varying thickness, about	1,000
2.	Hard quartzose grit	5
3.	Compact basalt	} variable.
3.	Soft crystalline basalt	} variable.
4.	White shale, hard and fine-grained, with fossil plants and sandstone	30
5.	Basalt, with much olivine	50
6.	White shale	15
7.	Columnar basalt	——
8.	Black carbonaceous shale	2
9.	Columnar basalt	50
10.	Coarse ferruginous sandstone	50
11.	Basalt, generally soft and containing much olivine	——
12.	(a) Pisolitic iron ore	0 6″
	(b) Carbonaceous black shale	10
13.	Basalt, soft, with olivine, about	100

The whole of this section is not exposed anywhere. The separate beds of which it is composed are of unequal distribution, and variable in thickness, and it frequently happens that great changes in the development of the different beds, both volcanic and sedimentary, take place in the course of a few miles. The only sedimentary formations which have an extensive distribution are the white shales Nos. 4 and 6, but even these are often very poorly seen south of the Bráhmani River, where they appear to rest directly upon the Dubrájpur grits, and to be inferior to all the basalt flows. It is from these white shales that all or nearly all the rich fossil flora of the Rájmahál group has been obtained. The principal fossil localities are in the northern portion of the hills.[1]

The trap rocks are all dark-coloured dolerites; they vary in character from a fine-grained, very tough and hard rock (anamesite), ringing under the hammer, and with the edges of its fracture almost as sharp as those of a quartzite, to a comparatively soft coarsely crystalline basalt. The latter usually contains olivine in large quantities. Many of the trap rocks are amygdaloidal, the enclosed nodules usually containing some form of quartz, either agate, chalcedony, or rock crystal. Occasionally, but less frequently, zeolites are found, stilbite being the commonest, natrolite less abundant; analcime has also been detected. It is not usual to find the cavities lined with green earth, as is so frequently the case amongst the amygdaloids of the Deccan series. The basaltic flows above the sedimentary bands are, as a rule, compact; the most amygdaloidal traps are Nos. 5 and 7 of the section.

Very little light is thrown on the source of the basaltic rocks by any observations within the Rájmahál area. Dykes are rare, and there is only one instance known of an intrusive mass which may mark the site of an old volcanic outburst. This is about 22 miles south-south-east of Colgong on the Ganges, close to a place called Simra, where a group of small conical hills occurs, composed of pinkish trachyte, porphyritic in places, and surrounded by Damúda rocks. The surface of the ground is much obscured by superficial deposits, but there appears good reason for supposing that the core of a volcanic vent is here exposed. It appears not an unfrequent occurrence that the later outbursts from a volcano are more silicious and less basic than earlier eruptions, and that a volcanic core, even when the lava-flows have been doleritic, should itself, when exposed by denudation, prove trachytic. This may be due

[1] The most important localities are Bindrabun and Burio, the former a small village situated about 4 miles south-west of Teliagarhi Fort on the Ganges, and 8 or 9 miles south-east of Pir Pynti station on the East Indian Railway; the latter a large village in the Morel valley.

to the solution of the highly silicious metamorphic rocks, through which the outburst took place, by the molten lava remaining in the fissure after the eruption, and the consequent conversion of that lava from a basic into an acid rock.

Reference has already been made to the evidence in favour of supposing that the trap dykes and intrusions in the fields of the Damúda valley are of Rájmahál age, and both dykes and cores of basalt are common in the portion of Birbhúm lying south-west of the Rájmahál hills. It is possible that the principal vents lay in this direction, or they may have been in the region now covered by the Ganges alluvium. The difficulty of determining the original source of eruptive rocks will be again illustrated in the case of the Deccan traps.

II.—Birbhúm, Deogarh, and Karharbári region.—All the Gondwána basins comprised in this group are of small size, and only lower Gondwána beds are found in them. They serve to connect the Rájmahál outcrops with those of the Damúda valley, and appear to indicate that the lower Gondwána beds once extended over a great part of Western Birbhúm and Northern Hazáribágh. For convenience sake they may be divided into two sections, eastern and western.

A.—Small basins of Birbhum, Deogarh, etc.—Scattered over the metamorphic country west of the Rájmahál hills and north of the Damúda valley, there are several small basins, principally composed of Tálchir beds, but occasionally containing Barákars also. They are of small geological importance and of no economical value, and they require but brief notice.[1]

1. **Tangsuli.**—About 6 miles south-west of the spot where the Dubrájpur beds and the traps of the Rájmahál area disappear beneath the alluvium north of Mahammad Bazar, and between 5 and 6 miles north-west of the civil station of Soory, the principal town in Birbhúm, there is a small tract of Barákar rocks about 2 miles long from north-west to south-east and a mile broad. The beds exposed are sandstones, grits and conglomerates, with some carbonaceous shales containing thin seams of coal of no economical value. The beds form apparently a small basin-shaped synclinal.

The only interesting point about this field is the absence of Tálchir beds. In this respect it differs from all the other Birbhúm fields. It is intermediate in position between the Ránigan coal-field, which commences nearly 20 miles away to the south-west, and the Rájmahál area,

[1] Of the greater number of these outliers no account has ever been published. It is consequently necessary to give a few details as to the position of each. The same remarks apply to the small basins in Hazáribágh, most of which were mapped several years ago by Mr. W. L. Willson.

and it is worthy of notice that throughout the north-eastern portion of the Ránigaňj field the Tálchir formation is absent, as in the Tangsúli basin, and the Barákars rest directly on metamorphic rocks, whilst in the Rájmahál area the Tálchirs, as has been already pointed out, are poorly represented, and are, as a rule, wanting. The Tangsúli basin should perhaps be classed in the same group as the coal-fields of the Rájmahál hills.

2. The next exposure of Gondwána rocks occurs about 13 miles west by north of the last. On the Sidh Nadi, about 6 miles west of its junction with the Mor, there is a small tract of sedimentary rocks about 4 miles from east to west and 1½ from north to south. It lies about 6 miles north-east of the town of Kandit, and consists entirely of Tálchirs. The southern boundary is a fault.

3. On the same stream, the Sidh, about 6 miles south-west of the last-named patch and 5 miles west-north-west of Kandit, is a very small basin of Tálchir rocks, about a mile in length from north-west to south-east, and less than half a mile broad. This basin is a simple synclinal.

4. **Kandit Karayah field.**[1]—This commences 4 miles north-west of the last; it is about 4 miles in extreme length from north-west to south-east, and rather more than a mile broad. Both Tálchirs and Damúdas are found, and the latter contain one or two very thin seams of coal, the thickest only measuring 14 inches. The greater portion of the field consists of Tálchir rocks. The beds have throughout a dip to the south-west, and are cut off in that direction by a fault extending the whole length of the field.

All the preceding fields are in Birbhúm; those next mentioned are in Saruth Deogarh, part of the Santhál Parganahs.

5. **Sahajori field.**—The next tract of Gondwána rocks commences within a mile and a half to the north-west of the last. It is much larger, being nearly 10 miles in extreme length from north-west to south-east, by about 2 miles broad where widest, and it covers an area of 11 square miles, of which 5 are occupied by Barákar rocks and the remainder by Tálchirs. The Barákars, which are about 400 feet thick, consist of the usual felspathic sandstones, grits, conglomerates and shales, with a few very thin seams of shaly coal. The Tálchirs are much thicker. The boundaries of the area are for the most part natural; a fault traverses the field from north-west to south-east, and there are a few other faults of smaller importance. The Barákars completely overlap the Tálchirs and rest upon the gneiss at the south-west margin of the area.

[1] For a more detailed account of this and the two following tracts by Mr. Hughes, see Mem. G. S. I., VII, pp. (247)-(255).

6, 7, 8, 9. On the Adjai river, which runs from north to south between the last-described tract and the Karaun or Jainti field, there is a patch of sedimentary beds about 3 miles long by a mile broad. Another little patch, only about a mile in length, comes in west of the river and north-west of the larger tract, and a third equally small is seen in the river, 3 or 4 miles north of the exposure first named. About 3 miles further south are two more patches just west of the river, and about half a mile apart, each about a mile long from north to south, but less than half a mile broad. All these little outliers are of Tálchir beds.

10. **Jainti or Karaun field.**—This is the largest of the small basins of Gondwána beds in the Deogarh and Birbhúm area; it commences about 3 miles west of the Sahajori field, and is about 16 to 17 miles in extreme length, but nowhere much more than 2 miles broad, and it is of peculiar shape, the greater portion of the field being a narrow band running west by north to east by south, with an extension for several miles to the southward from the eastern extremity. The area comprised is 24 square miles, of which only 5 consist of Barákar rocks, the remainder being Tálchir. This field lies west of the Adjai river, rather more than 20 miles south of Deogarh, and the southern extremity lies about 6 miles north of the town of Jamtarra. The Jainti area is traversed by the chord line of the East Indian Railway.

The relative positions of the Tálchirs and Barákars in this field differ from those observed in the Sahajori and Kandit Karayah basins in one important point. In both the other areas the general dip of the beds is south-west, and the fields are more or less cut off by faults along their south-west boundary. In the Jainti or Karaun field there is certainly a fault along the extreme southern boundary of the portion which extends south from Karaun, but the main area lying north of Karaun rests upon the gneiss to the south and dips northward, the northern boundary consisting in great part of a fault running a little north of west. This fault is therefore parallel to the great fault boundaries of the Damúda valley, though the throw is in the reverse direction.

The Barákars are in two separate patches along the northern boundary, the eastern being much the larger of these patches. Some thin seams of inferior coal have been found in them. The Tálchirs, both in this and in the Sahajori field, are well developed, and boulders of great size occur in many places amongst them. These boulders comprise, besides granitic and gneissic rocks, quartzites apparently derived from the rocks of the Khárgpúr (Kurrukpoor) hills distant about 60 miles to the north by west near Monghyr. Concretions of impure argillaceous

limestone are not uncommon in portions of the Tálchirs, and a few fossil plants have been found in these concretions.

11. A small basin of Tálchir rocks, 4½ miles long and about a mile broad, occurs on the Patro Nadi, 14 miles south-west of Deogarh, and 11 north of the extreme western end of the Jainti field.

B.—Small basins of North-Eastern Hazaribagh, including Karharbari.—This group of basins is merely a continuation of the last to the westward, and it comprises in the same way a number of small detached tracts, chiefly consisting of Tálchir rocks and dispersed over the surface of the metamorphic country. Only one is of much economic importance. It may be mentioned here that no basins have been found in the northernmost portion of the Hazáribágh district, and only one extends for a very short distance into any part of Monghyr.

12. A second patch of rock on the Patro Nadi, about 3 miles west of that last mentioned, and situated partly in Parganah Kharagdiha of Hazáribágh, partly in Parganah Chakai belonging to Monghyr. It consists entirely of Tálchirs, and covers less than a square mile of ground.

13. A small tract of Tálchirs, barely a mile long, on the Jaintí Nadi, 11 miles south by east of the last, and 4 miles west of the extreme end of the Jaintí field.

14. An irregularly-shaped area, 6 miles south of the last, and a short distance north of the Barákar River, about 6 miles long from north to south, and varying from a mile to 3 miles broad. It is close to the villages of Deopúr and Ehalapúr.

15. A long basin extending for more than 10 miles along the Barákar river, where this stream forms the boundary between the districts of Hazáribágh and Manbhúm. The western edge of this basin is between 5 and 6 miles south of the Karharbári coal-field. All the four basins hitherto mentioned contain only Tálchirs.

16. **Karharbari (Kurhurbalee) coal-field.**[1]—This small field has attracted great attention, in consequence of the superior quality of the coal found in it. It lies 17 miles south-south-east of the town of Kharagdiha, 16 miles north-east of the high hill of Pareshnáth, close to the Grand Trunk Road, about 15 miles west of the Jainti field and about 23 miles due north of the Jharia coal-field in the Damúda valley. It is 6½ miles in extreme length from west-north-west to east-south-east, and about 2¼ miles broad, and it comprises 11 square miles, of which 8 consist of Karharbári rocks, and the remainder of Tálchirs, with some inliers of the metamorphic formations. The elevation of the plain, composing the greater portion of the field, above the sea, is about 900 to 1,000 feet.

[1] For a description of this coal-field by Mr. Hughes, see Mem. G. S. I., VII, pp. (209)-(246). Some additions have been made from MS. notes.

The northern and southern boundaries of the field are faulted in parts, and nearly straight, running in each case about west-north-west to east-south-east. The throw, however, is very small, that of the south boundary not exceeding 100 feet, and in places, along this boundary, the sedimentary beds are found south of the fault. The field is traversed from west-north-west to east-south-east by other faults, the most important of which appears to form the southern boundary of a large gneiss inlier on which stands the village of Karharbári, and then, running along the northern base of Bhadwa hill, to split into several minor faults to the eastward. Independently of the faults the beds dip generally from all the boundaries towards the middle of the field. Except in the neighbourhood of the northern and southern faults, the rocks are, as a rule, very little disturbed.

The rocks found in this basin consist chiefly of the Karharbári group, already described in the fifth chapter, and Tálchirs. Some conglomerates of small quartz pebbles, which occur in the south-eastern part of the field and extend thence to Lumki or Kamaljor and Bhadwa hills, probably belong to the Barákar group, the chief evidence in favour of separating these conglomerates from the Karharbári group being that they appear to be slightly unconformable to the underlying rocks, and that in some shales, associated with a seam of coal on the hills mentioned, *Schizoneura gondwanensis*, a *Sphenopteris* common to the Barákars, and some other plants occur, not hitherto found in the underlying Karharbári group, whilst the typical Karharbári fossils appear to be wanting. With the exception of this probable outlier of the Barákar group, no representative of any portion of the Damúda series or of any later sedimentary formation is found in the Karharbári field.

The Tálchirs extend throughout the whole of the western boundary and the greater part of the eastern. They are, however, overlapped by the Karharbári group on the eastern boundary near Buriadih, and have not been traced on the south-eastern corner of the field. The village of Karharbári in the western part of the field stands upon a large metamorphic inlier, $1\frac{5}{8}$ miles long from west-north-west to east-north-east. This inlier is surrounded by Tálchir beds except to the south, where the Karharbári beds are brought against the crystalline rocks, apparently by a fault.

The whole thickness of the Tálchirs in this field, where they are best developed, is about 600 feet, and they consist of the usual shales and fine sandstones, the former containing boulders in places. The Karharbári beds are about 500 feet thick, and comprise white and grey felspathic sandstones with grits, conglomeratic beds, shales, and three or four coal seams.

The quality of some of the coal seams is equal, if not superior, to that of the best coals found in the Rániganj field, and is very little, if at all,

inferior to that of good English steam coal. The principal coal seam, which is close to the bottom of the Karharbári group, is from 12 to 16 feet in thickness. The other seams are thinner, not exceeding 7 or 8 feet. All furnish good coal, the best being that from the lower or main seam.

Dykes of volcanic rock are numerous, and some of them seriously injure the coal seams with which they are in contact. Their directions vary.

The Karharbári coal-field, despite its small size, is economically of far greater importance at present than most of the larger fields, as from it is derived the main coal supply for the East Indian Railway.

17. A basin of irregular shape, consisting entirely of Tálchir rocks, traversed in parts by the Barákar river, about 4 miles south-west of the Karharbári field. It is about 7 miles in extreme length from west-north-west to east-south-east, but very narrow, nowhere much exceeding a mile in breadth.

18, 19. Two small patches of Tálchir rocks exposed on the banks of the Barákar above the last. The first is about 2 miles distant from No. 17, and is nearly 2 miles long; the second is half a mile further, and occupies less than a quarter of a square mile.

20. The next three basins are also entirely composed of Tálchir rocks; they lie north-west of Kharagdiha, close to the upper part of the Sakri river, which runs to the north into the Ganges. The first is about 18 miles north of that last specified and 8 miles west by north of Kharagdiha. It is only about 1¾ mile long from north-west to south-east, and rather less than a mile broad.

21. Another tract, 3½ miles north of the last, is scarcely larger.

22. The third of these outlying areas of Tálchir rocks lies close to the large village of Bhandári. It is chiefly north of the Sakri river, but is intersected by the stream in its south-western corner. It measures about 3½ miles from east to west and 2½ from north to south. To the north-east is a detached portion, just separated by the intervening metamorphics.

23. Further down the Sakri, some 8 miles north-west of Bhandári, and about a mile south of the village of Gowan, conglomerates, which have been referred to the Tálchirs, are seen in the banks of a tributary stream. They occupy a very small area, not more than a few hundred yards in length. Five or six miles north-west of this again, near the villages of Deothan and Pihira, two other small outcrops are seen, one north, the other south, of an alluvial valley watered by streams running into the Sakri.

Scarcely any of these small tracts of Gondwána rocks are of sufficient size to enable them to be represented on the general map published herewith.

CHAPTER VIII.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF COAL-FIELDS, ETC.

III, DAMÚDA VALLEY REGION — A, Damúda valley coal-fields — 1, Ráníganj (Raneegunge) — 2, Jharia (Jherria) — 3, Bokaro — 4, Rámgarh — 5, South Káranpúra — 6, Káranpúra — B, Coal-fields of Northern Hazáribágh, Southern Behar, and Palámaun (Palamow) — 7, Chopé — 8, Itkúri — 9, Daltonganj — 10, Unsurveyed basins in Palámaun and Lohárdagga — 11, Morhar river south-west of Shergotty.

THE coal-fields of the Damúda valley form a chain of Gondwána basins running east and west, and separated from each other by very short distances. The eastern fields are in the comparatively open and undulating country near the border of the Gangetic alluvial plain, but the western fields are situated in a trough-shaped depression, between the plateaus of Hazáribágh and Chutia Nágpúr (Chota Nagpore), both of which rise to a height of more than 1,000 feet above the level of the Damúda river.

The Damúda valley lies south of the tract in Birbhúm and northern Hazáribágh, over which the basins described in the last chapter are distributed, the area of the two regions being close together to the eastward, but separated to the westward by the Hazáribágh plateau, on which no Gondwána rocks are found, with the exception of one small outlier. The small basins near Hazáribágh and Daltonganj are classed with the present group: they shew the passage to the more extensive areas of the Son (Soane) valley.

The Gondwána basins described in the present section are the following:—

A. Damúda valley—

1. Ráníganj.
2. Jharia.
3. Bokáro.
4. Rámgarh.
5. South Káranpúra.
6. Káranpúra.

B. Northern Hazáribágh and Southern Behar—

7. Chopé.
8. Itkúri.
9. Daltonganj.
10. Unsurveyed basins in Palámaun (Palamow) and Lohárdagga.
11. Morhar river near Shergotty.

A.—Damuda valley coal-fields.—1. Raniganj (Raneegunge).—The Rániganj, formerly known as the Burdwan, coal-field,[1] from the district in which a portion of its area is comprised, lies in the valley of the river Damúda, which traverses the field from west to east. The town of Rániganj is 106 miles north-west of Calcutta, and the northern extremity of the coal-field is about 25 miles south-west of the southern end of the Rájmahál area. The extent of the known tract occupied by the Gondwána series near Rániganj is about 500 square miles, the field being about 39 miles from east to west, and 18 from north to south; but there is no doubt that the rocks of the coal-field extend farther to the east under the laterite and alluvium which conceal the surface. In this direction the Damúda rocks and their associates, together with the underlying metamorphic formations, disappear completely beneath the thick alluvial deposits of the Ganges valley, which extend for about 300 miles to the eastward. The Barákar river, flowing from the north-west, joins the Damúda in the western part of the Ránigan coal-field, whilst the northern portion of the field is traversed and drained by the river Adjai.

The Ránigan field has been known for a long time, and its geology has received attention for the last 30 or 40 years. It has thus furnished the typical sections of the rocks, sections with which all those found in other parts of India have been compared. So far as the lower Gondwána formations are concerned, the sequence is more full, and the different sub-divisions are better represented, in the Ránigan area, than in any other in Eastern India, and the only tract which can compare with it in interest is that exposed in the Sátpúra hills south of the Narbada valley. The latter, however, has been far less carefully surveyed; the country is wild and covered with jungle, and the Damúda beds greatly concealed by rocks of the upper Gondwána series and by the Deccan trap; moreover, the amount of investigation for commercial purposes by boring, mining, &c., is very large in the Ránigan coal-field; very small, and confined to a limited area, in the Sátpúra basin.

The rocks are, on the whole, fairly exposed in the Ránigan coal-field, although the lower sub-divisions—the Tálchirs, Barákars, and ironstone shales,[1] as is usually the case amongst the Gondwána rocks—are much better seen than the higher, owing partly to the former existing in parts of the area in which there is less alluvial covering, partly to the greater tendency of the latter to decompose into a sandy clay which conceals the surface. There is, however, no question that much might now be added to the knowledge of the geology and palæontology of the field by

[1] A full account of this coal-field is given in Mem. G. S. I., III, pp. 1-195.

a fresh survey; because, since the year 1860, when the country was last examined geologically, the number of collieries, in the upper beds or Rániganj group especially, has largely increased, and the presence of seams of coal has been ascertained by boring in places where none were previously known to exist.

The rocks found in the Rániganj coal-field, and their approximate vertical extent where thickest, are the following:—

	Feet.
1. Mahádeva? (? Dubrájpur)	500
2. Panchet	1,500
3. Damúda—	
A. Ránigauj	5,000
B. Ironstone shales	1,400
C. Barákar	2,000
4. Tálchir	800
	11,200

The general dip is approximately from north to south, the lowest beds being exposed along the northern border of the field. The southern dip is, on the whole, wonderfully persistent. In the northern portion of the area it is low, usually about 5°, and rarely exceeding 10°, but towards the southern edge of the field there are great rolls of the strata, and, frequently, high dips. Finally, at the southern edge the whole of the Gondwána series are turned up at high angles, then cut off abruptly, and metamorphic rocks come to the surface. Whether this abrupt termination is due to faulting or to the rocks having originally been deposited against a cliff is a disputed point.[1]

Independently of this boundary there are several large faults in the field, of some of which no trace is seen on the surface, but they are revealed, as is so frequently the case, by mining. Along the northern boundary several nearly parallel faults, with a general north-west south-east direction, throw the rocks in succession, each having a downthrow to the north-east. One patch of Barákars thrown by the fault farthest to the north-east is quite unconnected with the field. Another fault runs for some miles almost down the bed of the Adjai river, and throws down, on its north side, the tract of Barákar beds containing the coal near Kásta.

[1] See pp. 103-106. That some faulting has taken place along this line is almost certain; it is impossible otherwise to account for the disturbance and crushing in the Gondwána beds immediately to the northward. Still the original estimate of the extent to which the rocks are thrown may be excessive, and the line of boundary may be approximately the original limit of the rocks. It is only right to say that all the surveyors who mapped the Ránigauj and the other Damúda fields are still disposed to consider these boundaries as faulted.

In the west of the field one important fault runs nearly north and south down the bed of the Barákar river: another running north-west and south-east forms the south-west boundary of the field for about 14 miles. This last fault is parallel to the faults on the northern boundary already mentioned, and the throw is in the same direction.

The Tálchirs are only found in the north-western portion of the field. They pass up into the Barákars north of Táldánga, a little west of the Barákar river, and at this locality they attain their greatest thickness, their upper portion consisting of coarse sandstones and conglomerates, with only occasional bands of the characteristic fine silty beds of which their lower portion is entirely composed. Proceeding either east or west from the locality named, the upper beds of the Tálchir group disappear, and although the thickness is but little less to the west, to the east it gradually diminishes as the Damúdas overlap bed after bed until the Tálchirs disappear completely. They are last seen in the Adjai river about 22 miles from the western extremity of the ficeld and thence to the eastward the Barákars rest on metamorphic rocks.

Boulders are not so commonly associated with the Tálchir rocks in the Rániganj coal-field as in some other areas. They are numerous, however, in the western extremity of the field.

No representatives of the Karharbári group have hitherto been detected in the Rániganj field or in the other basins of the Damúda valley, but it is highly probable that, amongst the passage beds hitherto classed with the uppermost Tálchirs or the bottom beds of the Barákars, Karharbári beds may have been included.

The greater portion of the basin consists of Damúda rocks, and the higher group, that of Rániganj, is not only very fully developed in this area, but it is rich in coal seams. Many of these seams are of considerable thickness, some of them even amounting to 20 feet. In this respect, however, they are exceeded by the Barákar seams, one of which at Kásta, in the northern part of the field beyond the Adjai river, is from 33 to 35 feet thick. The Barákar seams in the Rániganj area, as a rule, are of inferior quality to those found in the Rániganj group: there are exceptions, however, some excellent coal being found in a Barákar seam near Cháuch, west of the Barákar river, and also at Benodakatta, east of the Barákar. One great cause of the inferiority in the Barákar seams is the prevalence of basalt running in strings through the coal and converting it into a worthless shaly mineral.[1] This is a very rare occurrence in the higher group, and it is very singular,

[1] Some of this altered coal exhibits columnar structure very finely, the hexagonal prisms formed being 2 or 3 inches in diameter.

because both groups are traversed equally by numerous basaltic dykes, some of them of large size. One of these dykes runs for 20 miles through the coal measures. The small dykes, which permeate the Barákar coal seams, may belong to an older series than the other dykes of the field, and may possibly have existed before the deposition of the Ràniganj group. Some of the Barákar coal exhibits a peculiar spheroidal structure, and round balls of various sizes, up to more than a foot in diameter, break away from the mass when the coal is mined. So thoroughly are these rounded that they were taken at first for rolled fragments derived from some older formation.[1]

The proportion of coal in the lower Damúda beds is at times large. In one of the best sections exposed in the west of the field—that seen in the Kúdia and Pasai streams—an aggregate amount of 175 feet of coal is exposed in a total thickness of 833 feet of rock, so that upwards of one-fifth of the whole is coal. A large portion of this enormous thickness, however, consists of inferior coal and shale not worth extraction, and some seams are injured by intrusive trap, but a considerable quantity of useful fuel could be obtained at this spot, though it is an exception to find any seam continuing unchanged throughout a large area. So irregular are the Barákar seams in thickness, that beds several feet thick are sometimes seen to thin out and disappear entirely within a few yards. This is especially the case when the roof of the coal consists of coarse sandstone, and in such cases there is evidence that, through some change in the circumstances of deposition, the coal has been swept away and sand has accumulated in its place. There is also, amongst the other Barákar beds of the Rániganj coal-field, a great tendency to vary in quality within short distances.

The ironstone shales, which overlie the Barákars, form a marked ridge of raised ground traversing the coal-field from east to west, their elevation above the other rocks being due, not to their hardness, but to their power of resisting disintegration. They thin out and are overlapped by the Ràniganj group in the south-west corner of the field, where their relations to the underlying Barákars are peculiar, and it is not clear whether the latter have been upheaved and denuded before the ironstone shales were deposited, or whether this spot has been the original margin of deposition of both groups.

Clay ironstone, both of the ordinary non-carbonaceous form, and also of the carbonaceous variety known as "black band," is found in considerable quantities interstratified with the shales. Ironstone nodules

[1] See J. A. S. B., XVII, Pt. 1, p. 59; XVIII, p. 412; XIX, p. 75; and Mem. G. S. I., III, p. 66.

also occur. The seams of clay iron ore vary in thickness from 2 inches to a foot, and occur at irregular intervals. The proportion which the ironstone-bands bear to the shales varies: in one measured section of 150 feet of shale, 26 bands of iron ore were met with, the aggregate thickness of which was about 8½ feet, or 1 in 17½; whilst in a pit sunk to a depth of 52 feet at Bádúl, the proportion was 1 in 9, but three quarters of the iron ore in this case was black band, which contains less iron. The shales appear in some places at all events quite impermeable to water—an important advantage in mining.

As has already been stated, the coals of the Ránigani group are in many cases of superior quality to those of the Barákar group found in this coal-field. The Ráuiganj seams are, moreover, constant in thickness and quality over larger areas than the Barákar seams, and the former are only known in a very few cases to have been seriously injured by volcanic rocks, the basalt dykes which traverse the rocks, as a rule, affecting only the coal in immediate contact, and not ramifying in strings through the coal seams. The proportion of coal to the whole thickness of beds is, however, very much less in the Rániganj group.

The rich seams of Rániganj itself are situated in ground so much covered with laterite and alluvial deposits that the relations of the beds are very difficult to trace. The strata associated with the coals appear, however, to be some of the highest of the group, and it is possible that these beds have elsewhere been removed by denudation before the deposition of the Panchet formation. At the same time this is by no means proved, and it is equally possible that the Rániganj coal-beds represent some of the seams found farther west about Chinakúri. The seams of Sitarámpur and Sánktoria, in the neighbourhood of Chinakúri, are on a much lower horizon than those of the Rániganj neighbourhood, and the coal is of superior quality, one bed yielding a good coking coal, which has of late been employed successfully in the manufacture of iron.

A band of ironstone in the upper portion of the Rániganj group affords great assistance in tracing out the relations of this group to the overlying Panchets, for the ironstone band can be traced, by the fragments found on the surface, over a large area, in which none of the other associated beds can be recognised with certainty. Here and there sections of the band are seen in streams, and some carbonaceous shales with intercalated seams of clay iron-ore are exposed, the mineral character being precisely the same as that of the thicker ironstone shales below. The ironstone band is found, at a maximum depth of 700 to 900 feet below the base of the Panchet group, throughout a large area in the western and southern portion of the field, but it is completely overlapped by

Panchet beds a few miles west of Asansol on the Grand Trunk Road. It reappears further east, but it cannot be traced in the neighbourhood of Rániganj for want of sections.

In the south-western portion of the coal-field a bed of magnesian limestone has been found in the lower portion of the Rániganj group,[1] and has been quarried to some extent, in the ground north-west of Panchet hill, for a supply of flux to the iron-works and also for burning into lime. The calcareous band comprises two beds near Bághmára, under Panchet hill, the upper bed being too impure and sandy for use, whilst the lower, which contains 63 per cent. of carbonate of lime, 14 per cent. of carbonate of magnesia, and 20 per cent. of sand and clay, is about 12 feet thick. The limestone has been traced over a considerable area to the north-eastward; becoming, however, more sandy and impure, and apparently dividing into smaller bands intercalated with sandstone at a distance from the original locality. Calcareous sandstones are common in the Rániganj group; this, however, is the only bed which has hitherto proved sufficiently rich in lime to be worth quarrying.

The Ránigan j group occupies a very large area, nearly half of the field being composed of it. The tract covered by the higher formations is comparatively small. The Panchets occupy a basin about 8 miles across in the middle of the coal-field, and extend to the southern margin; they are also found in two smaller areas along the southern edge of the field; one of these areas surrounds Panchet hill, the highest and largest hill in the coal-field, on all sides except the south.

The change to the Panchet beds is usually marked by the occurrence of red clay on the surface of the ground. The felspar, which forms a considerable proportion of the sandstones of the Panchet group, remains undecomposed instead of being converted into kaolin as in the Damúdas: the sandstones of the former group are consequently more fusible, and the bands of hard semi-fused rocks, on each side of the basaltic dykes traversing the beds, stand out like walls in places near the Damúda river. The Panchets are extremely micaceous throughout.

The bed containing the reptilian remains mentioned in the general description of the Panchet group[2] is best exposed in the bed of the Damúda near the village of Deoli,[3] about a quarter of a mile east of the mouth of the Besram stream, and close to the right (south) bank of the river. The same bed is seen in some other places on the river bank and it was traced by Mr. Tween, who collected most of the bones, over

[1] Mallet, Rec. G. S. I., X, p. 148.

[2] *Ante*, p. 133.

[3] This was the case in 1860; a change may have taken place subsequently in the river channel.

a considerable tract of country near the middle of the synclinal basin occupied by the Panchets.

Along the southern border of the field is a line of hills, Panchet, Garangi, Beharináth, and some smaller rises south of Ráníganj, the upper portions of which are composed of coarse ferruginous grits and conglomerates, quite distinct from any beds found in other parts of the field. These rocks were at first supposed to be an upper subdivision of the Panchets, but it appears more probable, now that we have a better knowledge of the rocks intervening between the Damúda and Narbada valleys, that these coarse conglomerates represent a portion of the Maháḍeva formation. There is also, as already mentioned, a probability that the grits and conglomerates may represent those underlying the traps of the Rájmahál hills. No fossils have hitherto been found in the Ráníganj field to aid in determining the age of the upper beds.

The relations of these grits to the underlying Panchets are extremely obscure, the hill sides on which the junction takes place being greatly concealed by pebbles and detritus from the upper beds. There is some appearance of the grits overlapping the lower beds and resting on the metamorphics. If this be the case it may also be found that the lower formations alone are faulted against the metamorphics.

In the eastern portion of the Ráníganj field a ridge of high land, running north and south, about 16 miles east of Ráníganj, consists of coarse yellow and white felspathic grit, with beds of white, bluish-grey, and mottled clay, and thin bands of hard quartzose ferruginous grit. These rocks are best seen in a railway cutting near Kálipúr. They stretch from Khyrasol, 17 miles east-south-east of Ráníganj, to the Adjai river, and similar beds are found to the northward near Soory and to the southward in Bankúra (Bancoora) and Midnapur (Midnapore). It appears possible that they do not belong to the Gondwána series at all. At the same time there is an equal possibility of their being of Rájmahál age, but no fossils have hitherto been detected in them.

The basaltic dykes of the field have already been mentioned. They are numerous, and although their direction varies greatly, a very large number run nearly north-west and south-east. This, as has already been noticed, is the direction of some of the most important faults in the field; but the dykes are clearly of later age than the faults, not a single instance being known, except in the case of the horizontal intrusions amongst the Barákar coal-seams, of a dyke being thrown by a fault, although there are a few cases in which a dyke runs along a fault. The apparent dislocation of the horizontal dykes in the

Barákar coal seams may be due to the intrusions following the direction of the coal, and not to the dykes being prior in age to the faults. The traps traverse all the rocks in the field except the Mahádevas: the latter occupy so small an area that it is impossible to feel assured that they are newer than the dykes, but still the absence of any volcanic intrusions amongst them is not confined to the Ránigani field. There are many dykes in the Panchet beds. At the same time, if the dykes are of older date than the Mahádevas, it is evident that the suggestion made above, that the Ránigani field and other portions of the Damúda valley were once covered by Rájmahál traps of the same age as the dykes, becomes untenable, because those traps would have been intercalated between the Panchets and Mahádevas.

Besides the dykes, some of which are of great length and breadth, some irregular basaltic intrusions are found in the eastern part of the field, and these become more numerous and larger to the northward, in the country between the Ránigani field and the Rájmahál hills. All the evidence tends to connect the dykes with the volcanic outbursts which produced the basaltic traps of the Rájmahals, and to prove that all the disturbances which affected the Damúda and Panchet groups preceded the Rájmahál epoch of volcanic action. It may as well be noted here that all the facts observed in connexion with the dykes of the other Damúda fields lying west and north-west of Ránigani lead to precisely the same conclusions with regard to the age of the dykes and their relation to the different groups.

The question of the possible extension of this coal-field to the eastward is one of considerable geological and economical interest. Coal has been found by boring several miles within the alluvial area, and the circumstance that fragments of coal were found at a depth of 390 feet in a boring for water at Calcutta renders it possible that Damúda beds may exist in other places beneath the alluvial plain of the Ganges delta.

2. Jharia (Jherria).—The Jharia coal-field[1] commences at a distance of 16 miles west of the south-western extremity of the Ránigani coal-field, whilst the north-east edge of the former and the western extremity of the latter are but 13 miles apart. The Jharia field is inferior to the Ránigani in size, being about 26 miles in extreme length from west by north to east by south, and nowhere more than 10 miles broad. It comprises an area of about 200 square miles. Like the Ránigani field it is traversed from west to east by the river Damúda, the major portion of the field lying north of the river.

[1] For a full account by Mr. Hughes, see Mem. G. S. I., V, pp. 227–336.

The geology closely corresponds to that of the Ráníganj field. The deposits of the Gondwána series are entirely surrounded by metamorphic rocks, and have a general dip towards the south boundary, where they are abruptly cut off by a long nearly straight line which appears to be similar to the same feature in the Ráníganj field, though the throw is of less magnitude. No beds are exposed above the Damúdas, the only groups represented being the Tálchirs and the three subdivisions of the Damúda formation. The total thickness of beds exposed amounts to 6,800 feet, consisting of—

	Feet.	Feet.
Damúda—		
Ráníganj group	2,200	5,900
Ironstone shales	700	
Barákar group	3,000	
Tálchir		900

The Tálchir group is completely overlapped in the extreme east of the field, and throughout the greater portion of the northern border it occupies but a narrow strip of country, nowhere more than half a mile, and usually less than a quarter of a mile, broad. In the west of the field, however, the Tálchirs occupy a considerable area. They present the usual features, consisting mainly of fine shales which split up into angular and acicular fragments. Some concretionary nodules of limestone are found in them. The boulder bed is well developed in many places.[1]

The Tálchirs in the Jharia coal-field appear to pass upwards into the Barákars as they do locally in the western portion of the Ráníganj field, and no distinct unconformity has been observed between the two. The Barákars occupy the greater portion of the field,[2] and are shaly on the whole, with thick felspathic grits and sandstones near their base. Coal is found throughout; the larger seams, however, are chiefly towards the base of the group. The general characters of the coal seams are the same as in the Ráníganj field: the quality of the coal is very variable, some seams yielding good fuel, whilst others are little better than shale. Some very thick seams have been noticed, one amounting to as much as 60 feet; but there is precisely the same variation in thickness in the case of each seam as was observed to the eastward. Many seams also, as in the Barákar group of the Ráníganj field, are traversed by strings and dykes of basalt in such a manner as to render the coal worthless.

[1] In the detailed account of this field, several carefully-measured descriptive sections of the different formations are given. An excellent section of the Tálchir group will be found l. c., p. 241.

[2] Detailed sections are given in the report, l. c., pp. 261, 266, 274, 280, 285, and especially p. 296.

Despite these drawbacks there is unquestionably a large quantity of very fair coal procurable in the Jharia field.

The ironstone shales do not form nearly so well-marked a group as in the Ránigaṇj field; they are best seen in the middle of the field and are represented towards the west in the Jamúni river by thin argillaceous shales and sandstones. Ironstones are less abundant than in the Ránigaṇj field; their quality is poor, and they are so silicious that the natives are unable to smelt them.

Of the Ránigaṇj group,[1] only the lower beds appear to have been preserved, all the higher portions, if they ever existed, having been removed by denudation. As a natural consequence, the valuable coal seams of Ránigaṇj, Sitarámpur, Chinakúri, &c., all of which are in the higher portions of the Ránigaṇj group, are unrepresented in the Jharia field, and but few coal seams have hitherto been traced in the latter area above the ironstone shales. The rocks of this group, moreover, are greatly disturbed in the Jharia basin, and are in general inclined at an angle which would seriously interfere with mining.

Basaltic dykes are nearly, if not quite, as common as in the Ránigaṇj field, and are in every respect similar to those described as occurring to the eastward.

3. Bokaro.—The River Bokáro, which traverses the basin from west to east before joining the Damúda, has furnished the name for the next coal-field,[2] in the eastern portion of which the two streams unite. The Bokáro tract of Gondwána beds lies to the south-east of the town of Hazáribágh, and, like the Rámghur and Káranpúra fields, occupies the low valley, whilst the ground both north and south is much higher and composed of metamorphic rocks.

The Bokáro coal-field commences only 2 miles west of the extreme western limit of the Jharia field, and extends for 40 miles from east to west. It is narrow, being nowhere more than 6½ miles from north to south, and the area occupied is about 220 square miles. It may be described as occupying in the main a trough-like depression between two parallel faults, one of which forms part of the northern boundary, and the other the greater portion of the southern; but about half of the northern boundary is natural, whilst the southern fault passes for a considerable distance within the field, rocks of the Damúda series being found for some distance to the south of it. These large faults run nearly east and west in this field, but smaller faults with a general north-north-west and south-south-east direction are met with, and probably belong to the

[1] Measured sections in detail are given, l. c., pp. 314, 315, 318, &c.

[2] For a full description by Mr. Hughes, see Mem. G. S. I., VI, pp. (39)-(108).

same system as the north-west and south-east faults of the Ránigauj field. They appear to be of later date than the great east and west faults, which are dislocated in places by the north-west and south-east throws. On the whole, the rocks of the Bokáro area are more disturbed than in the fields to the eastward.

In the middle of the field, about half way between the extreme east and west boundaries, Lúgú (Loogoo) hill rises to a height of 1,500 feet above the valley, and 3,450 feet above the sea, the top being above the general level of the Hazáribágh plateau. This hill consists of Mahádeva rocks.

The formations exposed in this field are the following; the thickness of several of the groups has not been determined :—

Mahádeva (formerly described as Upper Panchets).
Panchets.
Damúda—
  Ráuiganj.
  Ironstone shales.
  Barákar.
Tálchir.

The field may be divided into three parts, the two extremities consisting almost entirely of Barákars, the central sub-division, which is the smallest, of the higher beds. The Tálchirs are but poorly developed, their principal exposure being on the western edge of the field. A few small patches are found along the northern border, and the same beds form a narrow margin for about four miles on the north-eastern boundary. They are overlapped in many places by the Barákars, which rest directly upon the metamorphic rocks throughout at least half of that portion of the boundary which does not consist of a fault. The Tálchirs are of the usual character, and the boulder bed is well developed, boulders being found occasionally in the upper members of the group as well as near the base.

The Barákars occupy about three-quarters of the whole field. Their mineral character exhibits no peculiarity; the conglomerate of small quartz pebbles at their base is well marked, and they contain numerous coal seams, some of them of considerable thickness, but the coal is variable in character, and, as a rule, of inferior quality. Still good seams occur, and others may be found by boring. Ironstones occur in the Barákars, and there appears, on the whole, a tendency to a passage from these beds into the overlying ironstone shales.

The ironstone shales are more fully developed in this field than in any other, being 1,500 feet thick, and they present precisely the same character as in the Ránigauj field. They pass downwards into the Barákars, being only distinguished by mineral characters, but there is

well-marked unconformity between them and the Ráuiganj group, the latter abruptly overlapping the former in places. The ironstone group, besides intervening between the Barákars and the Ránigaɲj beds east of Lúgú hill (both are wanting immediately to the west), occurs in a small tract in the north-west of the field, where both it and the overlying group are let in by faults, and it occupies several tracts in the south-west of the field south of the great fault, which forms a large portion of the southern boundary. A few other patches of ironstone shales occur, but they are small and of no importance. The ironstones themselves are rather silicious and inferior in quality to the bands associated with the Barákar group.

The Ránigaɲj group occupies a tract of about 14 square miles in extent to the east of the Panchet area around Lúgú hill, and is again found near Basatpúr in the north-west corner of the field, resting on the ironstone shales. The mineral character is the same as in the fields to the eastward, but scarcely any useful coal seams have been detected amongst the beds of this group in the Bokáro area.

The Panchets occupy a tract in the middle of the field; Lúgú hill is entirely surrounded by them, and the basal portion of the hill itself composed of them. They consist of the usual micaceous sandstones, green silty beds, and red clays, the latter not in such thick beds as in the Ránigaɲj field. Their unconformity to the Damúdas is more striking in this field than in that of Ránigaɲj, for, although they rest on the Ránigaɲj beds to the eastward, they completely, within the short distance of about a mile, overlap both the Ránigaɲj group and the ironstone shales north of Lúgú hill, and to the west they rest upon the Barákar beds. The mode of overlap is characteristic, and apparently due to the Damúdas having been upheaved and denuded before the Panchets were deposited, the latter, where dipping at an angle of 15°, being seen to rest upon the former, dipping at 25° to 30°. The Mahádevas compose all the upper portion of Lúgú hill, and consist of coarse conglomerates, grits, and sandstone, much impregnated with iron, and having generally a reddish colour; they precisely resemble the beds of Panchet hill in the Ránigaɲj field. As frequently happens in the rocks of the upper Gondwána series, the sides of the hills are so much covered by pebbles and detritus, that it is difficult accurately to ascertain the relations between these beds and those of the underlying group. The rocks of the hill are nearly horizontal.

Basaltic dykes are common in the Bokáro field, but they appear to have no prevailing direction; as usual they traverse all the groups except the Mahádevas. They appear to be of the same age as in the Ránigaɲj field.

4. **Ramgarh.**—The Rámgarh coal-field[1] lies due south of the Bokáro area, the distance between the two where nearest being only 3½ miles. This present field derives its name from the old town of Rámgarh on the Damúda river, near the western extremity of the area, and is of an irregularly triangular form, its greatest length, from east to west, being 14 miles; it is broadest at the eastern extremity, where it measures about 8 miles from north to south, and it diminishes rapidly in breadth to the westward, until it is not more that a mile broad; it, however, continues for between 5 and 6 miles to the west beyond this narrow portion, and exhibits a breadth of from 1 to 2 miles. The whole area is about 40 square miles. The field is traversed throughout its entire length from west to east by the river Damúda.

There is again in this small area a repetition of the peculiar characters remarked in the eastern fields; a general dip of the rocks to the southward, and an abrupt and faulted southern boundary. The direction of the western portion of the boundary is nearly due east and west as in the Bokáro field; in the eastern portion, however, the strike is east-south-east. The western part of the field is much cut up by cross faults running north-north-west and south-south-east; these dislocations, as in the Bokáro field, appear to be of later date than the east and west faults.

No rocks higher than the Rániganj group occur in the Rámgarh field. The groups exposed, with their approximate thickness, are the following:—

Damúda—	
Rániganj group	?
Ironstone shales	1,200
Barákar group	3,000
Tálchir	850—900

The Tálchir rocks occupy a considerable area in the extreme north of the field, and they again occur on the eastern boundary, but they are overlapped by the Damúdas throughout the greater portion of the eastern and northern borders of the Gondwána area, and they only appear in two small patches along the north-western boundary and in another at the extreme western end of the field. In one spot they are found on the southern fault, which traverses them at a place where its throw is very small. The boulder bed is well developed to the north.

The Barákars are the only beds in the field which are developed over a large area, and they present an unusual thickness. They are of the same character as in the neighbouring coal-fields, and consist of grits, sandstones, and shales, with conglomerates of small white quartz pebbles

[1] For a full description by Mr. Ball, see Mem. G. S. I., VI, pp. (109)-(135).

towards the base. Coal seams are numerous; the quality, as a rule, appears inferior, but some good beds occur. No attempt, however, has been made to explore the field by boring and mining.

The ironstone shales are much less carbonaceous than in the Ráníganj field, and consist of argillaceous shales and sandstones, with a few bands of poor clay ironstone. The area occupied by the group does not exceed half a square mile, and, with the exception of a small outlier on the Damúda, due south of Púnú village in the east of the field, the ironstone group is confined to a tract a little east of Rámgarh, where it intervenes between Barákar and Ráníganj beds. This tract, the only portion of the Rámgarh area in which the Ráníganj group is found, is surrounded by faults on all sides. The rocks of Ráníganj age occupy nearly a square mile, but they are much disturbed by faults, and no coal seams have been detected amongst them. Only one basaltic dyke is found in the field.

5. South Karanpura.—The two Káranpúra fields conclude the list of the Damúda valley coal basins. They lie due west of the Bokáro and Rámgarh fields, and in close proximity to them, only a mile intervening between the Bokáro and Káranpúra tracts, and about 2½ miles between the field of Rámgarh and that of South Káranpúra. The South Káranpúra is a small portion separated from the main field by a narrow belt of metamorphic country, but as the southern field extends farther to the eastward it may be noticed first.

The South Káranpúra field[1] is 22 miles in length from east to west, its average breadth being 4 miles; its extreme breadth near the eastern extremity 5 miles, and the area occupied 72 square miles, 3 of which, however, are composed of an inlier of metamorphic rocks. The Damúda river traverses the field from east to west.

The southern boundary consists as usual of a fault, which cuts off all the sedimentary rocks, none of them being found on the southern side of the throw; the general dip is, as in the other fields, to the southward. The rocks exposed consist of—

- Mahádeva (formerly described as Upper Panchets).
- Damúda—
  - Ráníganj.
  - Ironstone shales.
  - Barákar.
- Tálchirs.

The Panchets being completely absent, though found both in the Káranpúra field to the northwest and west, and in that of Bokáro to the north-east.

[1] For a full description by Mr. Hughes, see Mem. G. S. I., VII, pp. (322)-(330).

The Tálchirs are very ill-developed. They occupy a little tract, about a mile long and barely half a mile broad, at the eastern extremity of the field, and another very narrow strip, about 2 miles long, on the northern boundary. Elsewhere throughout the northern and eastern boundaries, the Barákar group rests directly upon the metamorphics. No Tálchirs are exposed around the large inlier of gneissic rock in the eastern part of the field, although the boundaries are natural. The Barákar beds occupy nearly three-quarters of the area, and appear to contain more coal than they do in the other fields of the upper Damúda valley; an appearance which may, perhaps, be due to better sections being exposed. Some of the coal is of fair quality, and bands of rich ironstone occur.

The upper Damúda groups are portion developed, though they cover a larger area than in the Rámgarh dild. They occupy a tract along the south boundary, nearer to the western than the eastern extremity, and about 9 miles long, but nowhere more than about 2 broad. The ironstone shales only occur to the eastward. To the west the Ràniganj beds overlap the ironstone shales, and rest on Barákars. Neither of the upper Damúda groups presents any features of interest.

The Mahádevas form two small hills, one of which, lled Henjdag, rests upon Ràniganj beds close to the eastern extremi th their area; the other in the extreme west of the field, called Patálickui, is larger, occupying an area of about two square miles, and res directly upon Barákar rocks. Not a trace of Panchet beds could be detected in either case, yet in both hills there is pseudo-conformity between the Mahádevas and the Damúdas, the rocks being very nearly horizontal. It is clear that in this case there must have been a break in time, represented in the neighbouring coal-fields by the Panchet group, between the period of deposition of the Damúdas and Mahádevas.

6. **Karanpura.**—The names of this and of the preceding field are derived from the parganah in which the greater portion of their surface is comprised. The Káranpúra[1] is second only to the Ràniganj field in extent amongst the basins of the Damúda valley. It commences at a distance of about 10 miles south-west of Hazáribágh; it is 42 miles in extreme length from east to west, and 19 from north to south, and it covers 472 square miles. The Damúda river runs for many miles through the south-western portion of the field; the eastern part of the area is drained by the Hohárú, a tributary of the Damúda.

[1] Described by Mr. Hughes,—see Mem. G. S. I., VII, pp. (285)-(321).

The formations found in the Káranpúra area are the following, with their approximate thickness so far as it has been ascertained :—

Mahádeva (Upper Panchets)	300
Panchets	?
Damúda—	
Ráníganj	?
Ironstone shales	600
Barákar	1,500
Tálchir	400

The form of the area is nearly elliptical, and the field has more of the characters of a basin than any other tract of Gondwána rocks in the Damúda valley. The highest beds occupy the middle of the field, and the lower formations roll up to the south of them. To the eastward the beds are cut off on the south by an east and west fault, which brings up to the surface the belt of metamorphic rocks intervening between this field and that of South Káranpúra. To the westward the field extends much farther to the south than to the eastward, the south-western portion consisting chiefly of Barákar rocks, but higher beds occur in a minor basin-shaped depression near the south-western corner, and the southern boundary appears to be along a continuation to the westward of the line of fault which limits the South Káranpúra field farther east.

In the rocks occupying this field a very important change has taken place in the relations of the different groups to each other. In the Ráníganj coal-field, the Ráníganj group is the most developed, and three groups, all of considerable thickness, intervene between the Mahádevas and the Barákars. All these intermediate groups thin out greatly to the westward, and their diminution in thickness is continued in the present field. Still farther to the west no rocks intervene between the Barákars and a great group of sandstones and conglomerates resembling, in mineral character, the Mahádevas of the Damúda valley and of the Sátpúra hills.

The Tálchirs occupy but a small tract in the Káranpúra coal-field, their whole area being but 9 square miles. They occur on the eastern edge of the field in several places, along the south-eastern boundary north-west of Patál hill in the South Káranpúra field, for about 6 miles, and again in the north-west of the field, where they extend for about 3 miles along the boundary, and run thence for some distance to the north-west up the valley of a small stream. They also surround an inlier of gneissic rock in the south-east of the field. Elsewhere, that is (excluding the faulted boundaries) throughout nineteen-twentieths of the margin of the field, the Barákars rest upon the gneiss. The Tálchirs present

no peculiarities; they are poorly developed, and consist of the usual shales and fine-grained sandstones with the boulder conglomerate at their base.

The Barákars cover about one-half of the basin, and almost completely surround the area occupied by the higher formations. They are much less shaly, and contain more sandstones than to the eastward; their coal seams appear less numerous, but several may exist which are not exposed at the surface. Roughly, the Barákars of the Káranpúra area may be divided into three sub-groups, the lowest division consisting of conglomerates of small quartz pebbles, coarse sandstones and grits, with some thick coal seams: the middle division contains no conglomerates; it is chiefly composed of sandstones which are less coarse than those below; it has coal seams of moderate thickness, and there are several beds of iron-ore: the upper division is made up chiefly of shales and shaly sandstones, with ironstones at the top, and the coal seams occurring are thin.

As usual, the coarse grits and pebble beds form low hills, and serve to mark out the outcrop of these beds and to distinguish the ground occupied by the lower members of the group from that covered by the higher sub-divisions, the surface of which is usually level like the area occupied by the ironstone shales and Rániganj group. Some of the felspathic sandstones of the Barákars weather into peculiar little pitted depressions, having a slight resemblance to foot-prints of animals. The relative thickness of different members of this group varies greatly in different parts of the coal-field, the same bed of sandstone being found in places to change in thickness within a short distance.

The principal band of coal is found about 300 feet above the base of the Barákars, and there is a seam of shale and coal, together 30 to 40 feet thick, exposed at this horizon in several parts of the field, and probably constant throughout. In places the thick seam is of even larger dimensions than those above given; in one section it measures 77 feet. In this respect, as in several others, there is an approximation in this field to the conditions existing in the Gondwána areas of the Central Provinces. The quality of the coal seam is variable, and a large portion of its thickness is mere shale. Some rich ironstones are also found in the Barákar group; the best are hæmatites, containing as much as 60 per cent of iron.

The ironstone shales are found in the northern and north-eastern portions of the field, where they form a belt, rarely exceeding half a mile in breadth, along the edge of the area occupied by the Rániganj group. To the west and south they are completely overlapped everywhere, but they occur around a small area of Ránigamj beds close to the southern boundary, near the eastern extremity of the field. The shales are paler

in colour, more silicious and much less carbonaceous than they are in the Ránigauj field. The ironstones too appear to be somewhat less rich.

The Ránigauj group forms, in the first place, a band about 2 to 3 miles broad on the average, surrounding the Panchet and Mahádeva area in the middle of the field; and, secondly, a much narrower belt in the little south-western basin around Gerwa hill. Ránigauj beds are also found in the south-east, near Chano, where they occupy a small area against the southern boundary faults. There is but little in their mineral character to distinguish them from the upper portion of the Barákar group, and where, as in the western part of this field, the intervening ironstone shales are absent, it is very difficult to draw a line between the two remaining groups of the Damúda series. Several seams of coal are found in the Ránigauj beds of the Káranpúra field, but the majority are thin, only a few being of sufficient thickness to be worth working. In one spot a gneiss inlier appears in the middle of the Ránigauj beds, and is supposed by Mr. Hughes, who mapped the field, to be an old peak which stood up in the middle of the area on which the rocks of the Gondwána series were deposited. This is not improbable, as the surface on which these rocks rest is very uneven.

The Panchets of the Káranpúra field occupy a considerable tract in the middle of the field, they and the overlying Mahádevas composing the surface throughout 90 square miles. The Panchets consist chiefly of coarser sandstones than those of the Bokáro field, and they are less micaceous. Red clays are common in the middle and upper portion of the group, but they are not distributed in thick beds as in the Ránigauj field; they are thinly laminated, and alternate with green micaceous clay.

The Mahádevas form the hills of Maudih and Sáthpahári in the middle of the field, besides a few scattered outliers, another rise about 3 miles long near Ganeshpúr on the west of the area, and Gerwa hill to the south-west. Of these Maudih hill is by far the most extensive; it is a plateau about 11 miles in length from east to west, and 5 from north to south. The rocks are the usual coarse sandstones, grits and conglomerates. In the south-eastern spur of this hill there is a remarkable example of the unconformity between the Mahádevas and the lower Gondwána series (Panchets and Damúdas), the conglomerates of the former resting upon Barákars faulted against Ránigauj beds.[1]

One remarkable point about the Káranpúra field is the paucity of the basaltic dykes so abundant in the eastern Damúda coal-fields. This

[1] In the map published in the Memoirs there is a mistake, the Mahádevas or Upper Panchets at this spot being coloured as Panchets proper.—See Mem. G. S. I., VII, p. (320).

probably indicates that the Káranpúra area is near the limit of the old outbursts of Rájmahál times. Further to the westward no dykes are found in the coal-fields until the area of the Deccan trap is entered. Faults too are less prevalent than in the other Damúda fields, and there appears thus some reason for connecting the origin of the principal dislocations in the Rániganj neighbourhood with the disturbances which preceded the outburst of the Rájmahál traps.

The country west and south-west of the Káranpúra fields has hitherto only been partly and imperfectly surveyed, and it is probable that closer examination may shew the occurrence of several small outliers of Gondwána beds hitherto unknown. The existence, on an isolated hill called Madaghir, 3 miles west of the Káranpúra field, of some sandstones belonging to the Gondwána series, has already been noticed.

B.—Coal-fields of Northern Hazaribagh, Southern Behar, and Palamaun (Palamow).—In this section will be comprised the fields of Chopé, Itkúri, Daltonganj, a small tract of Tálchir rocks near Shergotty, and a few other basins which have not yet been surveyed. The Daltonganj field, and all the other areas named, except Chopé and Itkuri, might equally well be referred to the next sub-division, as they are in the Son (Soane) drainage, but it seems best on the whole to place them here. There is, in fact, no line to be drawn between the Bengal and Behar fields and those of Chutia Nágpúr and South Rewah, and there appears to be a very great probability that all were once part of a continuous area.

7. Chope.—This is probably the smallest tract of Gondwána rocks containing coal yet detected in India. The peculiar interest attaching to this small area, from its position on the top of the Házaribágh plateau, has been already noticed.

The Chopé field,[1] which is traversed by a stream called the Mohani, is about 8 miles west by a little north of Hazáribágh, and at nearly the same elevation as the station, or about 2,000 feet above the sea. Small as the field is, it offers a repetition of some of the characteristic features of the Damúda coal basins. It is subtriangular in form, about a mile and a half in extreme length, from west by north to east by south, and rather less than a mile broad in a direction at right angles to the length, and it consists of Tálchir and Barákar rocks dipping to the southward with an anticlinal roll in the middle, and cut off along the southern border by a fault running from west by north to east by south.

The Tálchirs skirt the field and reappear in a small inlier, produced by the anticlinal roll above mentioned, and surrounded by Barákars, in

[1] A description by Mr. Ball is given in Mem. G. S. I., VIII, pp. (347)-(352).

the middle of the area. The beds of the Tálchir group consist of fine greenish sandstones with the boulder bed. The Barákars occupy the remaining tract. Only a small thickness of them is exposed in the only section available, that seen in the Mohani stream, but they comprise one bed of very shaly and inferior coal about four feet thick. The rocks of this small field are very poorly exposed.

8. **Itkuri.**—The Itkúri coal-field[1] lies about 25 miles north-west of Hazáribágh, and nearly as far north of the Káranpúra field. It is 15 miles long from east to west, but very narrow, being nowhere more than 2 miles broad, and the whole area consists of Tálchir beds, with the exception of one small patch, about half a square mile in extent, occupied by Barákars. The boundaries are mostly natural, a small fault cutting off the only outcrop of Barákar beds to the north-east, and bringing up metamorphic rocks against it. Neither Tálchir beds nor Barákars present any peculiarities; the latter contain some beds of inferior coal.

Two areas of Tálchir rocks are mentioned in the description of the Daltonganj field[2] as being found in the Hazáribágh district, besides those already mentioned. Both occur on the road from Balumáth to Chutro in Lohárdagga.

9. **Daltonganj.**—This coal-field has been known for many years under the name of Palámaun (Palamow), and the coal was worked formerly and sent down the Son river to the Ganges. The name of Palámaun, which is that of a sub-district or parganah of the district (zillah) of Lohárdagga in Chutia Nágpúr, being inapplicable, because other tracts of sedimentary rock occur within its limits, Mr. Hughes substituted that of Daltonganj, the civil station lying just beyond the southern border of the field.[3]

The Daltonganj coal-field, which is traversed by the Koil river, a tributary of the Son, lies about 50 miles nearly due west of Hazáribágh, and is a long irregularly-shaped tract, with very tortuous boundaries. It extends about 50 miles in length from east to west, and varies in breadth from 1 to 8 miles, its total area being 200 square miles. It is basin-shaped, the boundaries being apparently natural. Several inliers of gneiss occur within the limits of the field, but they are not extensive. Some small outliers of Tálchirs are scattered around the field.

The only formations represented are the Tálchirs and the Barákar sub-division of the Damúdas. The former are about 500 feet thick, and comprise the usual rocks, sandstones being more prevalent than shales, whilst the boulder bed is well developed. The Tálchir beds occupy more than four-fifths of the area. The Barákars are restricted to a tract nearly

[1] For description by Mr. Hughes, see Mem. G. S. I., VIII, pp. (321)—(324).
[2] l. c., p. (346).
[3] For a description of this field by Mr. Hughes, see Mem. G. S. I., VIII, pp. (325)—(346).

10 miles in extreme length from north-west to south-east, and 4½ broad, with an area of 30 square miles. The lithological character of the group is different to what it is in the Damúda coal-fields, the sandstones, which form the bulk of the formation, being friable, slightly calcareous, yellow in colour more frequently than white, composed of alternating fine and coarse layers, and very false bedded, the general appearance being intermediate between typical Barákars and typical Ránigani sandstone. It must be borne in mind that this field is beyond the area within which the Ránigani group has been found to exist.

Seams of coal are few in number, and only one, which contains about 5 or 6 feet of fair coal, is of sufficiently good quality and thick enough to be of value. It varies in thickness.

Only one intrusion of basaltic rock has been found in this field.

10. Unsurveyed basins in Palamaun and Lohardagga.—In the description of the Káranpúra field, mention has already been made of the probable occurrence of several small basins of Gondwána rocks in the country to the west and south-west of the Upper Damúda valley. Two of these outcrops have been briefly mentioned[1] by Mr. Hughes. They are the following :—

Sathbarwa.—This is a halting place 15 miles south-east of Daltonganj on the road to Ranchi. Only Tálchirs have been observed.

Latiahar.—This is another halting place on the same road 26 miles south-east of Daltonganj. Tálchirs, Damúdas (Barákars), and Mahádevas occur, the latter being largely developed. The Barákar beds are unusually ferruginous, and are consequently not easily distinguished from the overlying Mahádevas. Very little coal has been detected.

Several other small basins are known to occur in the Palámaun country, and the extent of ground over which they may be found cannot as yet be accurately defined. Far to the south on the top of the Chutia Nágpúr table-land, there is a report of coal occurring near Khurea, 24 miles north-west of Jashpúr. This report, however, depends solely on native information, and there is much reason to doubt its accuracy.

The last outcrop to be mentioned lies as far to the north of Palámaun, as the Jashpúr basin, if it exist, would be south.

11. Morhar River, south-west of Sherghotty.—At the small village of Gangti, 20 miles south-west by west of Sherghotty, and 4 miles west by south of Emámganj, there is a small exposure of Tálchir beds in the bed of the Morhar river. The only interest attaching to this outcrop is due to its occurrence on the edge of the Gangetic alluvium and the consequent indication of a possibility that Gondwána rocks may exist, beneath the alluvial formations, in this part of the Gangetic plain.

[1] Mem. G. S. I., VIII, p. (346).

CHAPTER IX.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF COAL-FIELDS, ETC.

IV. SON, MÁHÁNADI AND BRÁHMANI REGION — 1, South Rewah and Soliágpúr — 2, Jhilmilli — 3, Bisrampúr — 4, Lakhanpúr — 4*a*, Outcrops in Chutia Nágpúr — 5, Korba — 6, Raigarh and Hingir — 7, Tálchir. Outliers of Tálchir beds in Máhánadi valley. V. SÁTPÚRA REGION — 1, Sátpúra basin — 2, Upper Tapti area — 3, Small areas on the lower Narbada, west of Hoshangabád.

IV. Son (Soane), Mahanadi, and Brahmani region.—The area occupied by the Gondwána formations in the centre of India differs greatly from that in Bengal. In the central region the sedimentary beds, instead of being scattered over the metamorphic country in a number of small detached basins, occupy an enormous tract extending from Jabalpur on the west to Sirgúja on the east, and from a little south of the Son to the neighbourhood of the Máhánadi near Sambalpúr. To the westward the sandstones disappear beneath the Deccan traps, and may be continuous under the covering with the Sátpúra basin. To the south-east a long narrow strip of Tálchir rocks all but connects the tract north of Sambalpúr with the Tálchir basin in Orissa. A glance at the map will show that, but for the overlying volcanic formations, there would be an almost unbroken band of Gondwána beds across the Peninsula, from near Hoshangabád in the Narbada valley to within 40 miles of Cuttack in Orissa, or throughout eight degrees of longitude.

No portion of this area has been geologically surveyed as carefully as the coal-fields of Bengal. The Sátpúra field, some detached portions of the great central mass, comprising its north-eastern corner near Singrauli, three small tracts in Sirgúja, and another forming the south-eastern corner of the main area near Sambalpúr, together with the Tálchir field in Orissa, have been more closely mapped than any others; whilst the enormous area in South Rewah, Sohágpúr, Bilaspúr (Chhatisgarh), Northern Sirgúja, and Udepúr (Chutia Nágpúr), has been only cursorily examined, and in some cases merely traversed.

In the western coal-fields of the Damúda valley, there is a diminution in thickness of the whole Gondwána system, mainly due to the

gradual thinning out of all the groups between the Barákars and the coarse, ferruginous sandstones and conglomerates which were formerly classed as Upper Panchets, and have been in this work referred to the Mahádeva series, and considered as of upper Gondwána age. This gradual disappearance of the intermediate groups is carried so far that in places the Mahádeva conglomerates rest directly on Barákar rocks. The same combination, a thick mass of sandstones, more or less conglomeratic, resting immediately on Barákars, prevails, so far as is yet known, in the upper Son valley (Sohágpúr and South Rewah) and throughout the Bilaspúr, Sambalpúr, and Tálchir coal-fields, but it is now clearly ascertained, in the neighbourhood of Sambalpúr, that the lower portion of the upper beds is of Damúda age. Precisely the same sequence occurs in the Godávari valley, where also the most conspicuous change in lithological characters, accompanied by unconformity, occurs between the Barákar beds and the next formation in ascending order, and where the group immediately succeeding the Barákars contains Damúda fossils. There is, therefore, a marked agreement between the Gondwána groups in the Godávari and those in the Máhánadi and Bráhmani valleys. How far the same classification should be applied in South Rewah remains to be seen, but it is certain that Damúda fossils occur in places at a higher horizon than that of the Barákar group.

In the Sátpúra area the rocks are very different. A full series of lower Gondwána beds is succeeded by an equally complete sequence of upper Gondwána strata. The middle group of the Damúda series greatly resembles, in lithological character, some portions of the upper Gondwánas, but, as a general rule, there is a marked contrast between the upper and lower sub-divisions of the system. It is consequently desirable to treat the Sátpúra region as a distinct section.

It is not practicable to sub-divide the remaining area, although it is extremely probable that when the formations of South Rewah, Sirgúja and Bilaspúr are better known, differences will be found which will justify the conclusion that the upper Gondwána beds in the north and the south were accumulated under different circumstances; still the fact that the Gondwána rocks are continuous from near Jabalpur to the neighbourhood of Sambalpúr, renders it impossible at present to draw a satisfactory line. In the present section, therefore, a brief account will be given of the principal tracts on the Son, Máhánadi, and Bráhmani valleys. It should be repeated that these coal-fields, with the exception of that near Tálchir, are not separated from each other by metamorphic rocks; in some cases they are connected by broad plains of Tálchir beds, and elsewhere they are merely inliers, exposed amidst hills of higher

sandstones, still belonging to the Gondwána system. The following areas will be noticed separately :—

1. South Rewah and Sohágpúr.
2. Jhilmilli.
3. Bisrampúr.
4. Lakhanpúr.
4*a*. Outliers in Chutia Nágpúr.
5. Korba (including Rámpúr and Udipúr).
6. Raigarh and Hengir.
7. Tálchir.

1. South Rewah and Sohagpur.—Of this enormous tract only a most imperfect account can be given.[1] Leaving out of consideration the extension to the westward along the edge of the trap country to Jabalpur, the area of Gondwána rocks stretches nearly 200 miles from east to west, from the Kánher Singrauli to the Son-Máhánadi[2], and for a considerable distance the tract is 60 miles broad.

So far as can be judged from the very imperfect examination hitherto made of this field, it agrees better in its petrography, and in the arrangement of the rocks composing it, with the area to the westward in the Sátpúra region, than with the Gondwána series in the Damúda valley. There is a general tendency to a northerly dip throughout the western part of the area, and again in the tract of Damúda rocks to the north-east in Singrauli. The northern boundary runs from east-north-east to west-south-west, and is for a considerable distance nearly parallel with the general course of the river Son, at a distance of from 5 to 20 miles south of the river. This boundary is very straight and of an abrupt character, and in places it is clearly a fault; fragments, both of Damúda sandstones and of the crystalline rocks which occur outside the Gondwána area to the north, being found crushed together into a breccia along the line of junction. The higher rocks, of later age than the Damúdas, occupy the area to the northward, in the western part of the Gondwána tract, near the upper Son (Sohágpúr), but they appear thence to extend to the eastward south of the Damúda area in Singrauli. In the western part of the area these higher beds overlap the lower Gondwána series and rest on transition rocks. The eastern boundary

[1] No general description has ever been published. The extreme western portion was comprised in Mr. J. G. Medlicott's account of the geology of the central portion of the Narbada district; Mem. G. S. I., Vol. II, pp. 97-270. Such details as are given of the remaining area are from manuscript reports by Messrs. J. G. and H. B. Medlicott and Mr. Mallet.

[2] Not to be confounded with the Máhánadi of Chhattisgarh and Orissa. There are several rivers of this name (which only means great river) in India.

is irregular, the Mahádevas extending far to the eastward in Sirgúja. To the south-east the boundary of the area now under discussion is formed by the Tálchir rocks, which connect it in that direction with the other Damúda tracts in Sirgúja and Chhattisgarh; to the south the Tálchir beds rest upon the gneiss, whilst to the south-west the whole Gondwána series is gradually overlapped by the Deccan trap scarp extending to the north-west from Amarkantak, and by the Lametas underlying the traps. These overlying rocks, where they first impinge on the area from the southward, conceal only the lower members of the Gondwána system; the higher members extend farther to the westward, and the highest of all, belonging to the Jabalpur group, form a narrow and interrupted band, extending at intervals round the northern margin of the Mandla trap plateau to Jabalpur in the Narbada valley. From the manner in which the Gondwána rocks disappear beneath the traps of this plateau, there is considerable probability that the former continue to some extent beneath the latter, and the South Rewah and Sátpúra areas may be parts of one continuous tract of Gondwána rocks.

Despite the imperfect knowledge as yet available of the geological details, it is clear that the principal sub-divisions of the Gondwána system, the Jabalpur, Mahádeva, Damúda, and Tálchir formations, are all represented in the South Rewah area. The Tálchirs occupy a large crescent-shaped tract of country in the north-east corner, on the Rehr or Rehand river, in south-eastern Rewah and Singrauli, the length along the curve of the crescent being about 50 miles, with an average breadth of 5 to 6. There are some smaller Tálchir outcrops in the same neighbourhood along the northern boundary of the Gondwána tract, but the largest is only 3 or 4 miles across. The great expanse of Tálchirs is south of the field, where these beds cover a tract, several hundreds of square miles in extent, around Korea, west of Sirguja, and extend thence to the westward until they disappear beneath the Amarkantak traps. As already mentioned, this expanse of Tálchirs has been accepted as the southern boundary of the South Rewah Gondwána basin.

The Damúdas are represented by the Barákars throughout the field, and this group, being of economic importance on account of its containing coal, has received more attention than the other beds. There appears, however, good reason for believing that some of the higher Damúda sub-divisions are represented to the westward in Sohápúr, because true Damúda plants were found by Mr. J. G. Medlicott in beds which he had at first classed as "Upper Damúda," *i. e.*, Jabalpur, and, as will be seen presently, there are some indications of the occurrence of an upper sub-division in South-Eastern Rewah.

In the Singrauli area and the neighbourhood of the Rehand valley, the Damúdas consist principally of coarse felspathic sandstones, shales being less abundant. The rocks dip at low angles, or are nearly horizontal. Coal has been found in several places, as at Kota, Nowanagar, Parari, &c., and although the seams, as a rule, are thin, that at Nowanagar is an exception, being upwards of 20 feet in thickness, and a portion being of good quality. In one case a conglomerate containing rolled pebbles derived from the Tálchirs was found by Mr. Mallet in the Barákar beds.

Further west, on the Gopat river, there is a great thickness of coarse felspathic sandstones with occasional flaggy beds, shales, and seams of coal, all of which, however, so far as they are known, are inferior. Beneath the massive sandstone, however, there are flags and shales with some coal seams, and below these again more sandstone, associated with which, at Keryli, there is a seam of coal about 5 or 6 feet thick and said to be of excellent quality. It is possible that in this case the upper sandstone represents the Rániganj group of the Damúda valley.

To the west of the Gopat valley the Barákars appear to be covered by higher members of the Gondwána system. The former crop out again to the south and south-west, and occupy a very large area in the valley of the upper Son in Soháppúr, where the river runs from south-east to north-west parallel to the scarp of the Amarkantak plateau. From the Son valley the Damúda tract extends to the east as far as Jhilmilli, south of the great upper Gondwána belt.

An excellent section of beds of Damúda (and probably Barákar) age is exposed in the Johila river, a tributary of the Son in Sohágpúr; a thickness of 3,000 feet altogether being exposed, including the Tálchirs. The Damúda rocks consist of sandstones above, shales and flags below, the seams of coal associated with them being of poor quality and thin. The same appears to be the case in the area to the eastward so far as it has been examined.

Above the Damúdas the typical Mahádeva sandstone, pebbly, false-bedded, and with thin bands of hard ferruginous shale, brick-red to dark-brown in colour, has been traced across the whole region, and it is mainly on the strength of this evidence that the Mahádevas of the typical Sátpúra area are correlated with their probable representatives in the Damúda valley. The Mahádeva group is probably, in South Rewah as elsewhere, unconformable to the underlying formations.

The higher groups are only known to the westward in Sohágpúr and south-west Rewah. They consist of a great thickness of coarse felspathic sandstone, forming, amongst other hills, that on which stands the hill fort of Bandúgarh, and resting upon lavender-grey and white shales.

Both the sandstones and shales are referred to the Jabalpur group, the characteristic fossils being found abundantly in the shales. With these shales there is associated locally a band of coal of peculiar character, consisting of fine layers of jet. A very common character of the Jabalpur beds in this area is local induration, the sandstones having the texture of a quartzite, whilst the shales become porcelanic.

Basalt dykes occur throughout the South Rewah and Sohágpúr area, and some of the hills of sandstone in Sirgúja are capped by overflowing trap. In places some dykes are horizontal, and certain basalts, apparently interstratified with the Barákars of South-Eastern Rewah, may be examples of horizontal intrusion, but they are thought by Mr. Mallet to have a close resemblance to contemporaneous lava flows. All the basalt, whether intrusive or overlying, with the possible exception of the case just mentioned, appears to belong to the date of the Deccan traps.

2. **Jhilmilli.**—At the eastern extremity of the great area of Damúda beds which extends to the eastward from Sohágpúr,[1] there is a small tract of Barákar rocks, known as the Jhilmilli field from a town of that name at its eastern extremity. This little field lies due west of the northern portion of the Bisrampúr field, from which it is only separated by a belt of metamorphic rocks not much more than 3 miles broad. It is possibly an integral portion of the South Rewah and Sohágpúr field, but it is separated from that field by a fault, and it is nearly isolated.

This little tract is about 25 miles in extreme length, but only covers about 35 square miles. It is south of the fault just mentioned which runs from east-north-east to west-south-west, or parallel to the fault bounding the northern edge of the South Rewah field. The rocks of the Jhilmilli field dip northward, and are cut off at the fault in the usual manner. To the north of this fault throughout the eastern half of the field, metamorphics occur, with large patches of Tálchirs, filling all the hollows; but further to the westward, towards Sanhat, Damúda beds may be found, the area not having been examined. To the southward is a great expanse of Tálchirs with gneiss inliers of large size, the Damúda beds resting usually on Tálchirs, but occasionally on metamorphic rocks. The only beds of later age than Barákars known to occur in the field are those of the hills of Káltangħát, Chama, and Tumarbári, which are probably either Kámthi or Mahádeva.

The Tálchirs around this field are chiefly remarkable for two circumstances. One of these is the occurrence in abundance, amongst the

[1] These notes are from a manuscript account by Mr. Ball.

boulders, of masses composed of the characteristic compact Vindhyan sandstone, approaching quartzite in character. The nearest source of this rock is in the Kymore scarp beyond the Son river, 70 to 80 miles distant to the northward. Similar rocks also occur to the southward in Chhattisgarh and Sambalpúr, but the distance is even greater. It is not probable that the boundary of the rock in this instance was very much nearer in the Tálchir days, because so large a portion of the intervening area is occupied by Gondwána formations, and these nowhere rest upon Vindhyan rocks within the limits mentioned.

The other remarkable circumstance is the occurrence amongst the Tálchir rocks of a very thin seam of carbonaceous shale and coal. This bed is only about 6 miles in thickness, and the coal is of inferior quality, but its occurrence in the Tálchirs is remarkable and unusual.

The Barákars present no peculiarity. Several coal seams occur, and some are of excellent quality, but none appear to be of great thickness.

The upper rocks of the Káltanghát and other hills are but imperfectly known, and are only provisionally referred to the Mahádevas. Some trap dykes are met with in this field.

3. Bisrampur.—The Bisrampúr field is a tract chiefly compôsed of Damúda rocks, in Central Sirgúja, and derives its name from the chief town of the Sirgúja territory.[1] This field is connected by the great expanse of Tálchirs on its western side with the Jhilmilli, Sohágpúr, and South Rewah fields, and to the southward with the Korba, Raigarh, and other tracts of the Máhánadi valley. The Bisrampúr field lies south of the great belt of Mahádeva rocks extending to the eastward into Sirgúja, and is separated from the Mahádevas by a rather broad metamorphic region.

The field is nearly rectangular in shape. It is about 24 miles in extreme breadth from east to west, 22 miles from north to south, and it comprises about 400 square miles. The northern boundary runs nearly east and west, and is marked as a fault throughout; the southern boundary is also faulted, and has a direction from west by north to east by south; the east and west boundaries are for the most part natural.

The rocks exposed are the following:—

	Approximate thickness in feet.
Mahádeva?	1,000
Damúda (Barákar)	500
Tálchir	200

The thickness assigned to the beds, with the exception of the Mahádevas, are mere approximations. The strata are, on the whole, nearly horizontal; they are greatly concealed by alluvium, and the only sections seen are in the beds of streams.

[1] Described in detail by Mr. V. Ball - Rec. G. S. I., VI, pp. 25-41.

The Tálchirs present no peculiarities. To the west and south they are portions of the great area outside the field; they are represented by two patches of small extent outside the northern border, and they skirt a considerable portion of the eastern margin of the field, extending in places up the valleys between the ridges of metamorphic and transition rocks. The original surface on which they were deposited around the Bisrampúr field appears even more irregular than usual, and in one instance a ridge of quartzite penetrates the field for 6 miles with Barákars abutting against it on both sides.

The boulder bed is well developed at the base of the Tálchirs, and occasionally, as usual, contains boulders brought from a distance. In one case, in the northern part of the field, the source of some granitic gneiss blocks was traced to a locality 3 miles away to the north.

The Barákars, although occupying so large an area, are but ill seen, the rock most commonly exposed at the surface being whitish grit or sandstone, occasionally containing pebbles. Coal seams are found in several places, but they are not very promising, many of them containing but inferior fuel, whilst none are more than 5 or 6 feet thick. Good coal has, however, been found in places.

Mahádevas only occur in the southern part of the field, where they form a range about 6 miles long, known as the Pilká hills. They consist of the usual grits and pebble conglomerates with hard quartzose sandstones, but they are less ferruginous than elsewhere.

Although these rocks are assigned to the Mahádeva group of the upper Gondwánas on account of their neighbourhood to beds belonging to that formation in the South Rewah area, it must be borne in mind that no fossils have been found in them, and that lithologically they are undistinguishable from the Kámthi beds of the Raigarh and Hingir field, in which fossils have been found.

The most interesting point about the Mahádevas (or Kámthis) in this field is the conclusive evidence afforded by them of unconformity to all the lower formations. Not only do they rest partly on Damúda and partly on Tálchir beds, and, overlapping both, rest upon the metamorphics, but they overlie the lower Gondwána groups in places where the latter are distinctly faulted against each other, the fault not passing into the Mahádevas above. Faults between the Tálchirs and metamorphics are also unconformably covered by the Mahádeva sandstones.

4. **Lakhanpur.**—Another small area of Barákars, the western portion of which has not been fully examined,[1] lies due south of the

[1] This field, like the preceding, has been mapped by Mr. Ball, and the following short account is from his manuscript notes.

Bisrampúr field, from which it is only separated by a belt, two to three miles broad, of Tálchirs with inliers of gneissic rocks. On this belt of Tálchirs, further east, rests the Mahádeva mass forming Pilká hill, which is only a mile from the north-eastern corner of the field. The name of the present field is derived from a town lying outside the south-eastern edge of the Gondwána area.

The Lakhanpúr field is about 9 miles long from north to south; its breadth has not been determined, its western extent being unknown. The northern and southern boundaries are faults; the eastern boundary for the most part appears to be natural. No beds above the Barákars are found within the area, which is much covered by alluvium, the only rocks exposed, as a rule, being in the river sections, which are numerous.

Several seams of coal are exposed, the best being one seen in the Chandnai stream at Katkona. This seam is 5½ feet thick where best seen, one half consisting of excellent coal, the other half being of rather poorer quality. Several trap-dykes are found in this field.

4a. Outliers in Chutia Nagpur.—These are, as a rule, of small importance and but little known. None has as yet been mapped, and it is quite uncertain how many there may be. It is certain that small patches of Tálchir beds are scattered throughout many of the valleys of Eastern Sirgúja, Udepúr,[1] &c., but none have as yet been traced on the main plateau of Chutia Nágpúr.

Some of the flat-topped hills in eastern Sirgúja are capped by plateaus of sandstone, belonging apparently to the upper Gondwána series. In some instances, as on Main Pat, a high plateau north of Udepúr, this sandstone is covered by basaltic trap, belonging evidently to the Deccan trap series, which is again capped by laterite. The sandstone on Main Pat is about 300 feet thick; it rests north of the plateau on Tálchir beds, elsewhere on metamorphics in general, though Tálchirs appear beneath it here and there. The Tálchirs to the north of the plateau extend in the form of a belt from 2 to 4 miles broad, for 16 miles north to Bisrampúr, where they dip under Barákars. One outlier of the Mahádeva sandstone rests on these Tálchirs, another on a hill of metamorphic rocks close by.

5. Korba, (Rampur, Korba, and Udepur.)—Only the northern and eastern portions of this tract have been surveyed, and that but partially; the remainder of the area is only known by traverses.[2] The

[1] Not to be confounded with Udepúr in Rájputána, nor with another State of the same name in the lower Narbada valley.

[2] The coal at Korba is described in Rec. G. S. I., III, p. 54. The Udepúr portion of the country is known from Mr. Ball's manuscript notes.

Rámpúr, Korba, and Udepúr field evidently forms an integral portion of that next to be described; and had a complete survey of the country been carried out, the two would have been described together. The small town of Korba, on the Hasdo river, being the best known locality for coal, gives its name to the field.

The tract of Gondwána rocks running southwards from Sirgúja expands considerably in breadth south of the lofty plateau of Main Pat, and west of Udepúr, and extends between 40 and 50 miles from east to west, or from east of the Mánd to west of the Hasdo. To the northward, west of Main Pat, this area is nearly cut off by metamorphic rocks west of Lakhanpúr, the only connection between the Korba area to the south and the Lakhanpúr field to the north being by means of a belt of Tálchir rocks 3 or 4 miles long. To the southward the Gondwána area extends down the Mánd to Gúrda. Altogether, the present field is about 80 miles in length from north to south.

The greater portion of this large tract of country appears to be composed of Barákar rocks. Tálchirs of course are scattered in the usual patches, sometimes filling up hollows in the previously-formed metamorphic surface, on the outskirts of the tract, whilst higher sandstones—whether belonging to the upper Gondwána series, (Mahádevas,) or representing the Kámthi beds of the Raigarh-Hingir field is not clear—extend in detached masses along the eastern side of the field, having been doubtless connected originally with the beds of Main Pat. Towards the south these upper beds form the great range of hills which separates the area of Damúda rocks on the Mánd from that on its tributary, the Kurkut.

Trap of the Deccan series caps some of these hills of the higher sandstones in the northern portion of the field. This is the case with the hill of Rámgarh in South-Estern Sirgúja; and there appear to be other outliers towards Main Pat.

Coal occurs in many places on the Mánd and elsewhere near Udepúr, several of the seams being of fair thickness and average quality, whilst at Korba an immense seam of coal and carbonaceous shale is exposed in the bed of the Hasdo. This seam is at least 90 feet in thickness, the greater portion, however, being very shaly, and all containing a large proportion of ash. Some of the coal, nevertheless, appears to be of sufficiently good quality for use.

6. Raigarh and Hingir.—This, the south-eastern extremity of the great Son-Mahánadi area of Gondwána rocks, was formerly known as the Gángpúr field, but as no portion of it is in the Gángpúr

territory, the present name was substituted by Mr. Ball.[1] The Raigarh and Hingir field is named from the two estates in which it is principally comprised; it consists of a belt of sedimentary rocks, rather more than 20 miles in breadth near Raigarh, extending for nearly 90 miles to the north-west from the neighbourhood of Sambalpúr, gradually diminishing in breadth to the south-east, and terminating in that direction in a long narrow tongue of Tálchir beds which extends for between 30 or 40 miles, and comes to an end close to the edge of the Tálchir coal-field. The north-western extension of this field forms that of Korba and Udepúr, briefly described in the preceding paragraphs. The south-western limit of the field is straight and faulted for a long distance.

The rocks found in the Raigarh-Hingir area consist of—

	Approximate thickness in feet.
Kámthi or Hingir group	1,000
Barákar	?
Tálchir	250

The Tálchirs present their characteristic features. They occupy the south-eastern corner of the tract, and, as already mentioned, the strip which serves nearly to connect it with the Tálchir field, and they appear in several places underlying the Barákars on the margin of the Gondwána area.

The Barákars occupy several isolated tracts. They occur on the Mánd river to the north-west, and there form part of the area stretching northwards to Udepúr and west towards Korba. East of the Mánd river this Barákar tract is covered by higher beds, which extend for about 10 miles before Barákars again appear, and occupy a considerable area, about 25 miles in length from north-west to south-east, in the north-eastern corner of Raigarh. Of this area about 200 square miles have been examined. They form a large inlier, entirely surrounded by beds of higher formations. Barákars also occupy a considerable tract of country in the south-east of the field, and a narrow strip of them extends up each border. In many places they overlap the Tálchirs, and rest on the metamorphic rocks throughout considerable distances, as, for instance, along the north-eastern boundary of the field for about 20 miles north-west of Rájpúr.

The Barákars consist of felspathic sandstones and grits, shales and coal. A great thickness of shaly beds, amounting altogether to about 500 feet, with coal seams and occasional intercalations of sandstone, is

[1] For fuller accounts of this field by Mr. Ball, see Rec. G. S. I., IV, pp. 101-107; VIII, pp. 102-121; and X, pp. 170-173.

exposed in the Baisundar river, north of Hingir. Elsewhere, the rocks exposed appear to consist chiefly of sandstones and conglomerates. In the neighbourhood of Rámpúr, north of Sambalpúr, the Barákars contain much brown hæmatite in nests and irregular bands. Of the coal seams known, the majority are thin and poor, but a few are more promising.

The Barákars have a general low dip towards the south-western border of the field; the amount is small, not exceeding 5° to 10°, and there is a considerable amount of rolling.

The Kámthi beds consist of coarse ferruginous sandstones and conglomerates, and beds of red shale, having altogether a Mahádeva character; no carbonaceous bands have been observed amongst these rocks. They form great masses of flat-topped hills, and are very nearly horizontal, and consequently unconformable to the disturbed and inclined Barákars beneath them. They resemble the Kámthis of the Godávari valley in lithological character, and they contain *Glossopteris browniana, G. indica, Vertebraria, Alethopteris lindleyana*, and *Schizoneura gondwanensis*,—all Damúda species which have never been found in the upper Gondwána series.

These beds occupy the greater portion of the field, the Barákars appearing from beneath them. The Kámthis overlap the Barákars north-west of Hingir, and rest upon the metamorphics. The streams cut deep gorges through the upper sandstones, and the underlying rocks are frequently exposed in the bottom of the valleys. Along the south-western boundary, the Kámthi sandstones are, for a considerable distance, faulted against Vindhyan rocks.

Some of the coarse sandstones may represent a higher horizon. It is, however, most difficult to trace separate divisions in a mass of sandstones all similar in character, and in which fossils are very rare.

Only one trap-dyke has been found in this area; the rocks traversed by the dyke are Barákars. A considerable quantity of laterite covers portions of the field.

7. Talchir coal-field.—This basin is named from the small town of Tálchir on the Bráhmani river, the residence of a petty rajah who owns a considerable portion of the country in the neighbourhood. The Tálchir coal-field was one of the tracts of Gondwána rocks first examined by the present Survey; it was actually the first of which any detailed account was published, and it is the area in which the distinctions between some of the different members of the series were first clearly ascertained—a circumstance commemorated by the name which has since been applied to the lowest of them.

The Tálchir coal-field[1] commences, as already noticed, only 3 or 4 miles south-east of the point where the long spur of Tálchir rocks extending eastward from the Raigarh-Hingir field terminates. The present tract is about 70 miles in length from west by a little north to east by a few degrees south, and it is nearly 20 miles broad where widest. Its area is rather less than 700 square miles. Nearly the whole field is comprised in the drainage area of the Bráhmani river, only the extreme western and south-western portions being within the Máhánadi watershed. The northern boundary is abrupt and faulted throughout; the southern boundary over part of its extent only. The evidence of faulting in the case of the northern boundary is more complete in this field than usual, the fault being divided and bringing portions of the lower beds to the surface between the divided branches, whilst the dislocation itself is marked by a quartz vein and a mass of breccia containing fragments of the sedimentary beds, precisely as in the similar case mentioned already as occurring in South Rewah. In the eastern portion of the field the general dip is north, increasing in intensity near the faulted northern boundary, but great rolls of the strata take place throughout this portion of the field, whilst to the westward the whole area is occupied by nearly horizontal beds belonging to the upper sub-divisions.

The groups represented in this field and their approximate thickness are the following:—

Mahádeva? } Kámthi }	1,500 to 2,000 feet.
Barákar	about 1,800 „
Tálchir	500 feet.

The Tálchirs occupy the south-eastern corner of the field; they reappear between the branches of the fault forming the northern boundary, and they are represented in the extreme west of the field, where they form the usual tongue-shaped extensions occupying old hollows in the metamorphic rocks. This field is the typical locality for the group; and all the usual constituent beds—boulder beds, shales, and sandstone—are well developed and characteristic. The boulder bed occurs at the base, the matrix being sometimes shale, sometimes sandstone, then follows fine greenish-grey tesselated sandstone, and, at the top of the group, there is a considerable thickness of nodular shale, in which pebbles and boulders are occasionally found. Some annelid (or molluscan) tracks and a few fragments of plants have been found in these beds.

[1] See Mem. G. S. I., I, pp. 33-88. The field has recently been re-examined by Mr. Ball, who has confirmed all the main features of the original mapping, and has added some important details, especially as to the relations of the higher beds in the field. See Rec. G. S. I., X, pp. 170-173.

The Damúda group is represented by both Barákars and Kámthis; the latter were originally described as Mahádevas, but further research has shewn that there can be scarcely any doubt of some of the beds in the western portion of the Tálchir field being identical with the upper group of the Raigarh and Hingir field. The Barákars occupy a very large tract in the eastern portion of the field, in which they stretch from the northern border nearly to the southern. They are also represented at one place in the extreme west of the field near Tipapáni in Rairakol, but, as a rule, to the westward, they are overlapped by higher beds. They are distinctly unconformable to the Tálchirs, and consist of white felspathic sandstone, coarse grey and brown grits, blue and carbonaceous shales, and some beds of inferior coal. At the best known coal locality, Gopálprasád, about 12 miles west of Tálchir, the combined seam of coal and carbonaceous shale is of great thickness, probably not less than 100 feet, in this resembling the seam already mentioned as occurring at Korba on the Hasdo, and the coal seams of Chánda in the Godávari area.

The upper beds are unconformable to the Barákars, the unconformity being not only shewn by overlap, but actually seen in a section at Patrapáda on the Medúlea stream and at another near Tipapáni.

The rocks resting upon the Barákars near Patrapáda consist of yellow and white sandstones with purple clays having some resemblance to the upper Kámthis near Chánda, and also to some of the Panchet beds in the Damúda valley. The beds near Patrapáda attain a thickness of at least 600 feet, and appear to be more disturbed than the conglomerates and grits which rest upon them. Similar sandstones and clays are found in other parts of the field, and, although no fossils have been found in them, they may be referred, with much probability, to the Kámthi group, like the rocks of the Raigarh–Hingir field.

The beds forming the higher portions of the hills, in the western part of the Tálchir field, consist of grits and conglomerates containing pebbles of gneiss, quartzite and sandstone; some of the sandstone fragments closely resemble Tálchirs, but may be derived from certain Vindhyan beds which are very similar to Tálchirs in mineral characters. These conglomeratic upper beds are all more or less ferruginous, and contain bands of jaspery ironstone like those in the Mahádevas of the Sátpúra hills and the Kámthis of Nágpúr. The apparent difference in the degree of disturbance, to which the beds supposed to represent the Kámthi group on the one hand, and the overlying conglomerates on the other, have been subjected, has already been mentioned; it appears probable that the last named represent some upper Gondwána formation, and

they may be referred to the Mahádeva series. They exhibit some resemblance to the Rájmahál beds of Atgarh near Cuttack. In the Ouli river south of Patrapáda the upper conglomerates are about 800 feet thick. The examination of the beds above the Barákars in the Tálchir field is very difficult, as the upper members of the series are found in a very wild, almost uninhabited country, destitute of roads and consisting of flat-topped hills covered with forest, and intersected by deep gorges. There has hitherto been no opportunity of mapping the sub-divisions in detail, and no attempt has been made at separating them in the map.

The rocks referred to the Kámthi and Mahádeva groups occupy nearly two-thirds of the area of the field, including, with the exception of the small strip of Tálchirs (and in one case Barákars) already mentioned, all the western half, or rather more than half. The upper beds also occur in some small patches along the northern boundary, the principal of which is a hill, called Konjiri, on the Bráhmani north of Tálchir.

No trap-dykes have been found in the Tálchir basin; it is probable that this country is beyond the area affected by either Rájmahál or Deccan outbursts.

Outliers of Talchir beds in Mahanadi valley.—A few very small outliers of Tálchir beds have been found to the south of the Raigarh and Hingir field; and it is probable that the number may be increased when the ground is carefully surveyed. The only importance of these outliers is the indication they afford that the beds of the Gondwána system formerly covered a wider area.

Of these outliers[1] three occur near the Ebe river or upon its banks about 10 miles north-west of Sambalpúr. None of these exceeds a square mile in dimension. A fourth is found just south of the Máhánadi and opposite to the junction of the Ebe. Another is met with about 40 miles farther south on the Paljor river, a tributary of the Ong; and yet another exposure of Talchir beds has been noticed on the Tel river, about 80 miles south of Sambalpúr.

V. Satpúra region.—In the preceding pages of the present chapter the belt of Gondwána rocks has been traced south and south-east from the great central area in the valley of the Son to the basins of the Máhánadi and Bráhmani in Orissa. It is now necessary to return to the Sátpúra range stretching westward from the neighbourhood of Sohágpúr in the upper Son valley, the area intervening between the two regions of Gondwána rocks being covered by the basaltic lava

[1] Ball, Rec. G. S. I., X, p. 172.

flows of the Deccan trap. In the western or Sátpúra region the relations between the Gondwána beds and the surrounding rocks are very different from those which are so generally seen elsewhere. Instead of merely occupying basin-shaped depressions in the older formations, the Gondwána formations occur in the Sátpúra hills as a vast inlier exposed by denudation and surrounded on all sides except the north, and for some distance on the south, by bedded volcanic rocks of later date.

The Narbada valley is a great undulating plain, chiefly covered by post-tertiary deposits, beneath which, in places, the older rocks are exposed. These are, in almost all cases, metamorphic or transition. To the north of the broad alluvial valley is a range of hills formed of Vindhyan sandstones capped with trap. To the south the ranges are formed of the Gondwána series, also capped by trap. East of Hoshangabád, the rocks of the latter series are nowhere known to extend to the north of a line drawn along the northern base of the hill range. Further west, however, a few representatives of the highest Gondwána group have been found to the north of the river, though still in the valley itself.

In the present section the following tracts will be described :—

1. Sátpúra basin.
2. Upper Tapti area.
3. Small areas on the lower Narbada, west of Hoshangabád.

1. Satpura basin.—The Sátpúra coal basin[1] derives its name from the great range of hilly country lying south of the Narbada valley and separating the drainage area of that river from those of the Taptí to the west and the Godávari to the east. The range is known under various names, one of which is Sátpura. The area occupied by the Gondwána rocks may be considered as extending from the neighbourhood of Jabalpur to Lokartalai, south by west of Hoshangabád, a distance of between 170 and 180 miles, but the little tract near Jabalpur appears to be completely cut off from that to the westward by the overlying volcanic rocks, which, west of Jabalpur, overlap the sedimentary beds, and project to the northward, until they rest upon the metamorphic rocks of the Narbada valley. The Jabalpur tract is, however, scarcely worthy of separate notice; it is entirely composed of upper Gondwána beds (Jabalpur group) and extends for at least 25 miles, with one interruption near

[1] For detailed descriptions by Messrs. J. G. and H. B. Medlicott, see Mem. G. S. I., II, pp. 97-267; X, pp. (133)-(188) and Rec. G. S. I., III, pp 63-70, and VIII, pp. 65-86. The distribution of the Gondwána groups on the maps published in the second volume of the Memoirs has since been ascertained to be erroneous, though the boundaries of the coal-field are, as a rule, accurately laid down, except on the Pench river.

Lameta Ghât, along the edge of the traps which cover all the country to the southward. The beds exposed consist chiefly of the usual lavender grey and white clays, and earthy sandstones, usually soft, but occasionally much indurated. They appear to rest in places on the metamorphic rocks, and in places to be faulted against them. Some coal is found in the Jabalpur group at Lameta Ghât on the Narbada; the seam is of small thickness and irregular, and the coal has the usual peculiar structure, resembling that of jet.

Another similar belt of upper Gondwána (Jabalpur) beds extends upward of 20 miles along the edge of the trap country east and south-east of Narsingpúr. It is broader than the tract near Jabalpur, as it runs in some places for 5 or 6 miles up the valley of the Omar, Sher, and other rivers, which cut deep gorges out of the overlying volcanic rocks. The beds exposed consist of conglomerates at the base, succeeded in ascending order by soft shales, some of them carbonaceous and containing bands of jet coal, which are in places nearly 2 feet in thickness, but generally much thinner. Resting upon the shales are coarse sandstones and grits, which probably represent the Bandúgarh sandstone of the South Rewah basin.[1]

The Sátpúra field proper may be considered as commencing on the eastward nearly due south of Narsingpúr, and as extending thence to Lokartalai, a distance of about 110 miles, whilst the greatest breadth at right angles to the above is nearly 40 miles. The Gondwána area is broadest to the eastward, where, however, it is greatly covered by trap; it contracts rapidly to the west of the Tawa valley.

Divested of its covering of volcanic rock, this tract would probably exceed 2,500 square miles in extent, without taking into consideration its extension to the eastward; the area of Gondwána rocks actually exposed is, however, less than 2,000 square miles. The greater portion of this region is drained by the valleys of the Hard and Sákar, Sitariva and Dudhi, all tributaries of the Narbada, to the eastward; whilst to the west a number of streams, the largest of which is the Denwa, unite to form the Tawa, the largest stream which joins the Narbada west of Narsingpúr. The south-eastern portion of the area, however, is not in the Narbada basin at all, but south of the watershed, and it is drained by the Kanhán and the Pench, both of which run south toward Nágpúr, and there unite with other streams to form the Wain Ganga, which joins the Godávari.

The general geological relations of the Sátpúra field resemble those

[1] On the published map there is some confusion between these sandstones and the Lametas which were at the time supposed to be the equivalents of the Mahádevas.

of other Gondwána areas in this respect, that there is a general dip across the field (in this case, as in South Rewah, from south to north), the lowest beds being chiefly exposed near the southern boundary, and that the northern boundary is, on the whole, very nearly a straight line. But it has been shewn that the upper Gondwána rocks in places overlap this line and rest upon the metamorphic rocks to the northward, and it has consequently been suggested that the original survey of the field was erroneous, and that the northern boundary is not a line of fault. It must, however, be remembered that the lower Gondwána rocks are nowhere known to overlap the boundary line; that there is good evidence in Bengal for believing that great disturbance took place after the consolidation of the lower Gondwána beds and before the deposition of certain upper Gondwána groups; and that it is quite possible that the main northern boundary of the Sátpúra basin may be along a line of fault affecting only or chiefly the lower Gondwána beds. It was clearly shewn in the original account of the Sátpúra basin [1] that the supposed line of fault bounding the Damúda beds to the north is distinct from that forming the northern limit of the Mahádeva series, and it is also shewn that the boundary of the latter is occasionally natural. It is true that some of the data upon which these views were formed may need slight modification, but there is still a probability that the general conclusion is correct.

The area north of the field being thickly covered with the gravels and other alluvial deposits of the Narbada valley, it is impossible to say that the lower Gondwána rocks do not occur in places; but judging by other Indian coal-fields, it is improbable, and hitherto all attempts to find them have proved a failure.

The northern portion of the field consists chiefly of great sandstone plateaus, composed of the sub-divisions of the Mahádeva formation. Towards the east and west these plateaus terminate to the northward in scarps, 800 to 1,000 feet high, overlooking the alluvial plain of the Narbada valley. The central portion of the field is composed of the mass forming the Pachmarhi or Mahádeva hills, rising to an elevation of 4,380 feet, and consisting of the typical Mahádeva (Pachmarhi) sandstone. The southern portion of the field is less hilly, being composed of lower Gondwána rocks, but these appear at a considerable elevation to the south-eastward on the top of the watershed between the Narbada and Godávari drainage, and in the high upper valleys of the Pench and Kanhán, whilst to the westward they occupy the much lower ground of the upper Tawa valley.

[1] Mem. G. S. I., II, pp. 231, 237, &c.

The following are the groups exposed in the Sátpúra basin, and their approximate thickness where most fully developed :—

UPPER GONDWÁNA—		
	Jabalpur group	? 1,000
Maháàdeva series—		
	Upper—Bágra group	800
	Middle—Denwa	1,200
	Lower—Pachmarhi	8,000
LOWER GONDWÁNA—		
Damúda series		
	Upper— Bijori group	4,000
	Upper— Motúr "	? 6,000
	Lower—Barákar group [1]	? 500
Tálchir group		1,000

The thickness of the Damúda groups is considerable, but has not been accurately determined.

It is quite unnecessary to describe these different groups in detail here, as a description of each of the Mahádeva and upper Damúda sub-divisions has already been given in the general account of the Gondwána series. All that is now requisite is chiefly to point out the distribution of the various groups within the area of the coal-field.

The Tálchir beds, consisting of the usual sandstones and clays, with boulders, occur continuously along the southern boundary. In some places, as at the head of the Tawa valley, south of Motúr, they are very thick, and are peculiarly well exposed on the hill sides. They are also found in several places along the northern boundary, always greatly disturbed and often faulted, their mode of occurrence being somewhat obscure. They are thus seen, beginning to the eastward, at Nibhora, west of the Hard river, where Bágra beds rest upon them; at Mopáni on the Sitariva, where they are associated with Barákars; in the gorge of the Anjar, above Fatehpúr; in the Amádi stream, near Bargandi; and around Ahoni on the Kukurkhadi stream, north of Pachmarhi. Except at Mopáni, the overlying rocks in all cases belong to high Mahádeva horizons, and are of course quite unconformable. In the upper Tawa valley the line of division between Tálchirs and Barákars is less marked than usual, the two groups appearing to pass into each other.

The Barákar is the only group in which useful coal has hitherto been found. Like the Tálchirs it is chiefly exposed near the southern boundary. It occupies a considerable area in the upper Tawa valley and in the Kanhán and Pench valleys; it presents the usual appearances and consists

[1] Whilst these pages were passing through the press, Dr. Feistmantel ascertained that a portion at least of the rocks hitherto classed as Barákars in the Sátpúra region belongs to the Karharbári group.

of felspathic brown, grey and whitish sandstones, flaggy beds, shale and coal. The coal seams in the upper Tawa are thin and, as a rule, inferior; they are, moreover, very irregular in thickness. There is much more coal in the Pench valley, and many of the seams are of considerable thickness and of fair quality; but the distance from all roads and the very hilly and difficult nature of the country to the northward have hitherto prevented this coal from being worked.

There is only one locality in which the Barákars[1] appear near the northern boundary; this is at Mopáni on the Sitariva, where they are much disturbed and tilted, Tálchirs appearing at the axis of a sharp anticlinal fold,[2] to the north of which the Barákars dip sharply; northward these are succeeded by Mahádevas with the same high dip; and the latter are covered up and concealed by the alluvium of the Narbada valley. All the Gondwána rocks are excessively crushed in this direction, and they are probably close to the boundary of the field, but no other rocks are seen, though both to the east and west metamorphic rocks come to the surface along the edge of the alluvium. An attempt to bore to the northward proved the alluvial deposit to be at least 491 feet thick. At this depth the boring was suspended, no hard rock having been reached.

To the south of the anticlinal the dip is lower, and there is much less crushing than to the northward. Three seams of coal occur, one 12 feet, the second 18, the third 14 feet thick, 2 feet of the last named being, however, shale; these seams have been worked for some years past by the Narbada Coal and Iron Company. The quality of the coal is fair, but not equal to the best coals of Bengal. The Barákars are faulted against Mahádeva beds belonging to the Bágra group just south of the colliery, and Mahádevas also cover the Barákars, close by to the eastward, and again at a distance of between 6 and 8 miles to the westward, the intervening ground being much concealed by alluvium. Altogether the little area of lower Gondwána beds about Mopáni has much the appearance of being brought up between two east and west faults.

The Motúr beds consist of sandstones, white or brown, with bands of red clay and some nodular limestone, and much resemble the Panchets of Bengal. The Bijori rocks are more like ordinary Damúdas, and comprise felspathic sandstones, flaggy beds and shales, sometimes earthy, grey or brown, and occasionally carbonaceous. No coal has been found in these beds. The area of these two upper Damuda groups is in the

[1] Probably Karharbáris: see note on last page.
[2] See Rec. G. S. I., III, p. 63.

great flats and hill ranges drained by the Tawa and its tributaries and lying south of the Pachmarhi range. They here occupy a large tract of country upwards of 50 miles in length and 20 in breadth where widest.

The lowest portion of the Mahádeva group consists of the thick massive sandstones and grits of the Pachmarhi hills. These are well seen in massive, nearly horizontal beds, along the scarp forming the southern face of the range. The Pachmarhi group is traced for some 60 miles from east to west, and its outcrop is, where widest, 12 miles across; but it is evident that the group is thickest here, and that it gradually thins out in both directions. How far this thinning out is due to replacement by beds having the lithological characters of the upper Mahádeva groups, and to what extent it is due to a difference in the amount of sediment deposited in neighbouring areas, is less clear: in places to the eastward the former certainly appears to be the case.

The Denwa group shews some repetition, at a much higher horizon, of the conditions which prevailed during the deposition of the Motúr sub-division of the Damúdas, and consists principally of pale greenish yellow and bright red mottled clay with subordinate bands of sandstone and some thin beds of limestone. This group is chiefly developed north of the Pachmarhi hills; it is overlapped to the west, but continues for a long distance to the eastward, though its appearance is less typical than in the Denwa valley.

To the Denwa group apparently must be referred the rocks seen in the Moran river, near Lokartalai, in the extreme north-west of the field. These beds consist of sandstones, shales (some of which are carbonaceous), and a seam of inferior shaly coal, about 4 feet in thickness, but apparently worthless for fuel. Some other coal seams have been proved to exist by boring, but none appear to be of value. The Denwa beds are brought up by an anticlinal, and are apparently only exposed for a short distance in the immediate neighbourhood of the stream. These beds were formerly referred to the Damúdas, but the discovery in them of *Ptilophyllum acutifolium* and *P. cutchense* has shewn that they must be referred to an upper Gondwána horizon.

The Bágra group is chiefly conglomeratic,—sandstones, limestones, and clays being of less importance. It extends almost throughout the northern edge of the field.

The Jabalpur group is chiefly found to th eastward; it forms nearly the whole of the sandstone area north of the trap and east of the Dudhi valley, but west of that river it is only represented by outlying patches. The most western of these outliers is at Chátar hill, a little west of the

Dudhi river. There is, however, an outcrop of whitish sandstone with white shale and pyritous coaly shale resting on the Bágra group near Zumáni, nearly due south of Hoshangabád, and this exposure appears also to belong to the Jabalpur horizon.

Trap-dykes abound throughout the whole area, many of them being of large size, and in places irregular intrusions of trap have a tendency to run horizontally between the layers of bedding. This is chiefly the case amongst the beds of the upper Gondwána series, and especially in the Jabalpur group.

2. Upper Tapti area.—This tract is entirely outside of the Narbada valley, and is situated on the head waters of the Tapti. It lies, at an elevation of 1,500 to 2,000 feet above the sea, on the plateau which forms the watershed of the Sátpúra range, and extends along the edge of the traps, intervening between them and the underlying metamorphics, throughout a considerable area west and north-west of Betúl.[1] The boundary of the volcanic rocks is here very tortuous, and forms a series of curves, owing to the irregular action of denudation. The sandstones and conglomerates between the traps and the metamorphic rocks vary greatly in thickness; throughout a considerable tract they appear not to exceed 100 feet, and they are often thinner. The bed in this case is conglomeratic and sometimes cherty, and it appears to belong to the Lameta group. But near the villages of Alampúr, Khettapáni, and Khamapúr, 25 to 30 miles west by north of Betúl, and again in the Tapti river about the same distance west of the station, soft red argillaceous sandstones, with harder bands, and occasionally with red shales or clays, are exposed, much resembling some of the Mahádeva formations, and probably representing a portion of the Gondwána series. No fossils have, however, been found in these beds.

3. Areas on Lower Narbada, west of Hoshangabad.—For some distance west of Lokartalai, where the Gondwána rocks of the Sátpúra field disappear beneath the Deccan traps, there is, along the southern edge of the Narbada valley, and at the base of the hills which occupy the country to the south, a line of disturbance in continuation to the south-westward of that seen along the northern boundary of the Sátpúra field. Along this line of faulting the volcanic layers are turned up sharply and dip to the south. From beneath them, here and there, small outcrops of sandstone appear, evidently belonging by their characters to the Bágra group of Mahádevas. The best exposure is in the Ganjál stream, 6 or 7 miles west of Lokartalai. Sandstones are traced

[1] Mem. G. S. I., VI. pp. (272)-(275).

at intervals for 4 miles further, and the line of disturbance continues for 25 miles.

Close to Barwai on the Narbada, about 100 miles below Hoshangabád, and 80 or 90 west by a little south from Lokartalai, some coarse conglomerates, with a matrix of clay, occur beneath another conglomeratic band containing oyster shells: the latter, which belongs to the cretaceous Bágh beds, being unconformable to the other. The lower conglomerate has now been recognised[1] as Mahádeva, and this recognition renders it probable that some of the other sandstones of the lower Narbada valley belong to the same formation. The Mahádevas of Barwai are of small thickness and rest on Bijáwar rocks. No trace of Damúdas can be detected.

Somewhat similar conglomeratic beds to those of Barwai have been traced, at intervals,[2] throughout a considerable area to the eastward, between Barwai and Hindia, intervening between the base of the traps and various older rocks, Vindhyan, Bijáwar, or metamorphic. These conglomerates, however, appear to be, as a rule, of later date than the Mahádevas, and to represent the Lameta group. Still, further examination will be necessary to test the presence or absence of Mahádeva outliers. In one case, at Bhorla, near Punássa, south of the Narbada, these conglomerates appear with nodular grey limestone resting upon them. The latter is probably a representative of the Bágh beds: the conglomerate may be Mahádeva. In this case the underlying rock is not seen.

West of Barwai the Narbada valley is entirely composed of trap for about 50 miles; beyond this distance inliers of metamorphic and Bijáwar rocks reappear. Around Bágh[3] there are several such inliers, and in all of them fossiliferous cretaceous beds, resting upon sandstones, intervene between the traps and the old crystalline rocks. The sandstones thin away to the northward, but become much thicker to the south. They occupy a considerable tract between the traps and the metamorphic rocks west of Bágh, but they gradually thin out again and disappear along the southern edge of the great metamorphic region of Chota Udepúr farther to the west. The great tract of metamorphic rocks extends westward to the neighbourhood of Baroda, whilst the valley of the Narbada to the southward is formed of trap, in which inliers of the sandstones, with the calcareous Bágh beds resting upon them, are exposed in places through denudation. There are several such inliers south of Bágh,[4] some others south of Chota Udepúr,[5] and the largest is south of

[1] Rec. G. S. I., VIII. p. 73.
[2] Mem. G. S. I., VI., p. (217).
[3] *Ib.*, pp. (211), (212), (307), &c.
[4] Mem. G. S. I., VI., p. (310).
[5] *Ib.*, p. (323), &c.

the Narbada, on the Deva stream, at the boundary between the small states of Rájpipla and Akráni. This inlier[1] is about 10 miles across from east to west and nearly as much from north to south. Below the traps are about 500 feet of calcareous shales belonging to the cretaceous formation, succeeded in descending order by sandstones and conglomerates, of which at least an equal thickness is exposed. There is apparent conformity between the two, and both tend similarly to increase in thickness to the southward. It is far from impossible that the sandstones may represent the Mahádeva formation.

Similar sandstones again occupy a considerable tract north-west of this Deva inlier and south-west of Baroda, at the edge of the alluvium of Gújrat. In no case has a trace of any lower Gondwána rock been detected in the lower Narbada valley; the conglomerates and sandstones, just mentioned as possibly of Mahádeva age, in this region, where their base is seen, rest upon the transition beds or gneiss, without any intervening band of Tálchir or Damúda rock. The country has not yet been examined sufficiently closely to prove the absence of lower Gondwána beds, and it is possible some may occur beneath the sandstones of the Deva valley, but it is extremely improbable that, if they do, no trace of them should have been detected in the numerous localities from Bágh to the neighbourhood of Baroda, in which the sandstones beneath the Bágh beds are seen resting upon older formations.

[1] Mem. G. S. I., VI, p. (347), &c.

CHAPTER X.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF GONDWÁNA BASINS.

VI. GODÁVARI REGION — 1, Inliers near Ellichpúr — 2, Inliers west and north-west of Nágpúr — 3, Kámthi area — 4, Bandar coal-field — 5, Outliers near Khair and Arjuna, south of Wún — 6, Wardha-Pránhita-Godávari basin — *a*, Wardha (Chánda) coal-field — *b*, Central portion — *c*, South-eastern extension to neighbourhood of Ellore and Rájámahendri — 7, Kamáram coal-field — 8, Singareni coal-field. VII. EAST COAST REGION — 2, Athgar — 3, Outcrops east of Rájámahendri — 4, Ellore — 5, Ongle outcrops — 6, Sripermatúr outcrops — 7, Trichinopoly or Utatúr.

VI. GODÁVARI REGION.—The area occupied by Gondwána formations in the Godávari valley is probably greater than in the drainage area of any other river. The name Godávari is restricted above Sironcha to the southern affluent of the river, but the northern branch, known as the Pránhita, and formed by the union of the Pen Ganga, Wardha and Wain Ganga, is equal in size to the main stream. The great Godávari belt of Gondwána rocks extends from a few miles south of Nágpúr, through the plains of the Pránhita and Godávari, to the coast alluvium in the neighbourhood of Ellore (Yelaur). A great part of this area is but imperfectly known, and only a few tracts have received more careful examination. It will be necessary to describe these tracts separately.

A detached area occurs at the edge of the trap region close to Nágpúr, and inliers are exposed within the trap boundary west and north-west of Nágpúr, and again near Ellichpúr in Berar. The latter localities are beyond the Godávari watershed, but it is best to consider them in connexion with those included in the latter, as they are intermediate between the Sátpúra fields and those of Nágpúr. Other outliers occur further to the south and south-east, and doubtless more remain to be discovered.

The following areas will be noticed under this general heading :—

1. Inliers near Ellichpúr.
2. Ditto west and north-west of Nágpúr.
3. Kámthi area.
4. Bandar coal-field.
5. Outliers near Khair and Arjuna south of Wún.

6. Wardha-Pránhita-Godávari basin.
   a.—Wardha coal-field.
   b.—Central portion from third to first barrier of the Godávari.
   c.—South-eastern portion from first barrier of the Godávari to the neighbourhood of Ellore and Rájámahendri.
7. Kamáram coal-field.
8. Singareni coal-field.

1. Inliers near Ellichpur.—Along the southern scarp of the great spur, which, separating from the Sátpúra range near Betúl (Baitool) and extending from east to west between the valley of the Tapti and that of its great affluent the Púrna, is known by the name of the Gawilgurh (Gáwelgarh) hills, there is, north and north-east of Ellichpúr, a line of fault, running east-north-east to west-south-west, and having a considerable downthrow to the south. Along the northern or upthrow side of this fault, sedimentary beds appear, in places, from beneath the Deccan traps forming the whole of the surrounding country, and extend for a considerable distance—in one case for several miles—along the base of the hills. These exposures are but 30 miles south-south-east of the sandstones in the Tapti west of Betúl.

The most western of these inliers occurs about 8 miles north of Ellichpúr, and extends east and west between 6 and 7 miles. For 16 miles to the eastward no sedimentary rock is seen in place, but in one spot, 3 miles west of Narha, some blocks of sandstone occur, and there may be a small outcrop. At Narha, about 22 miles east by north of Ellichpúr, the sandstones reappear north of the fault, and extend for 15 miles. They then disappear again, but two smaller inliers, each about a mile long, occur at short intervals just beyond.

In these inliers Lameta (cretaceous) beds occur immediately beneath the basaltic traps, and are succeeded in descending order by about 500 feet of strata comprising felspathic sandstones, white and brown conglomeratic beds, occasional ferruginous beds, and thin layers of white and purple shale. It has not been decided whether these rocks are of Kámthi age or whether they should be referred to the Mahádeva series, no distinguishable fossils having been found.

No beds of Barákar or Tálchir age have been detected, and the base of the sedimentary beds is not seen, whilst an attempt to discover coal by boring proved unsuccessful. Metamorphic rocks appear in one place along the southern edge of the sandstone, and are apparently brought up between two faults with their throws in opposite directions. As these faults coincide at each end of the strip of metamorphics, there is evidence in this instance of two throws in opposite directions having taken place along the same line of weakness.[1]

[1] For further details see Mem. G. S. I., VI, pp. (277)–(283).

2. Inliers west and north-west of Nagpur.—These inliers are about 30 miles east of the last mentioned, and are three in number.[1] Two occur close together near the villages of Chorkheri and Kútkheri, about 30 miles north-west of Nágpúr; the third near Bazárgaon, about 20 miles west of Nágpúr.

The Chorkheri inlier is only 4 miles in diameter from north-west to south-east and 3 miles broad. That of Kútkheri lies 1½ miles to the south-east of the other, and is only a mile in length. The Bazárgaon inlier is 10 miles from east to west, and 5 from north to south. The only beds exposed in any of these inliers belong to the Kámthi group. The existence of these patches of sandstone proves that similar beds in all probability underlie the traps in this part of the country over a considerable area.

The only rocks found are coarse, gritty, felspathic sandstones and occasional bands of hard compact shale, red or yellow in colour. In the Bazárgaon inlier some of the sandstones are conglomeratic. No trace of Barákar beds has been detected in these inliers.

3. Kamthi area.—Immediately north of the town of Nágpúr, a small tract of Gondwána rocks appears at the edge of the trap area,[2] and extends from the village of Kámthi, whence the military cantonment of Nágpúr derives its name, to the small town of Kelod, a distance of rather more than 25 miles from south-east to north-west; the greatest breadth of the tract at right angles to the above is 9 miles. The north-eastern boundary appears to be straight or nearly so, and is probably a fault, but it is ill seen throughout the greater portion of its length. Beyond it to the north-east the country is composed of metamorphic gneissic rocks, but both the gneiss and the sandstones are greatly concealed by alluvial deposits of considerable thickness. The south-eastern boundary appears to be natural and tortuous, metamorphic rocks appearing just beyond it in several places. To the west and south the sandstones disappear beneath the Deccan trap. The area occupied by sedimentary rocks of the Gondwána series somewhat exceeds 100 square miles.

This tract of sedimentary beds has long been known, having attracted attention from being in the neighbourhood of a large town, and from some of the fossiliferous beds being extensively quarried. The area has moreover been exceptionally fortunate in having been thoroughly explored by the late Mr. Hislop. The only groups represented are Tálchirs and Kámthis.

1 Mem. G. S. I., IX, p. (313).
2 For fuller description, see Mem. G. S. I., Vol. IX, pp. (295)-(330).

The Tálchirs are represented only in two places. The first of these is near a village called Korhádi, about 6 miles north of Nágpúr, where some reddish and olive-grey shales occur in streams just east of the road from Nágpúr to Chhindwára. These shales contain large rounded boulders of metamorphic rocks and of the characteristic Vindhyan quartzite-sandstone and limestone. The Vindhyan fragments are probably derived from a considerable distance, as no outcrop of this formation is known near Nágpúr. The other Tálchir locality is a small isolated hillock known as Koda Dongri, which is surrounded by alluvium, and lies on the edge of the sedimentary tract north of the village of Pátan Sáongi, 14 miles north of Nágpúr. The hillock consists of vertical beds, apparently of Tálchir age.

The Kámthi beds are here seen in their typical locality, and are composed of the rocks already mentioned when describing the group as a whole. They occupy the whole area of sedimentary beds, with the exception of the two minute patches of Tálchirs specified above. They are well seen at Kelod, again south of Sáoner, and also south of Pátan Sáongi, and along the edge of the traps from Tondakheri to Bhokára north of Nágpúr; but the best known exposures are at Silewára, 9 miles north of Nágpúr, and Kámthi. At both of these places large quarries exist, from which numerous fossils have been obtained. The most characteristic beds are the coarse felspathic sandstones, brown, red, or white in colour, with bands of hard ferruginous grit, and the compact yellow and red shale. There is not a trace of carbon left in the plant fossils, and as the Barákars appear to be completely absent in the area, there is no probability of any coal occurring.

4. Bandar coal-field.—Around the town of Chimúr, about 30 miles north-east of Warora in the Chánda district, a considerable tract of Tálchir beds is exposed, resting to the east and west on metamorphic rocks, and to the south and south-west on Vindhyans, whilst to the north and north-west it is covered by the Deccan trap and infratrappean Lameta beds. This Tálchir area is about 18 miles in extreme length from north to south, and about 10 miles broad.

In the north-western corner, a few miles north-west of Chimúr, there is a small tract, of triangular form, occupying about 5 to 6 square miles, and composed of Kámthi beds resting upon Barákars. This small area has received the name of the Bandar coal-field.[1] The Damúda beds are covered by infratrappean beds to the north, but elsewhere rest upon the Tálchirs, and they occupy the axis of a synclinal

[1] For a full account by Mr. Hughes, see Mem. G. S. I., XIII, pp. 145-154.

basin. The Kámthis overlap the Barákars to the north-east, but the latter underlie the greater portion of the field, their presence having been proved, throughout a square mile, near the village of Bandar, by borings.

The character of the rocks differs in no respect from that in the neighbouring Wardha field. A maximum thickness of 38 feet of coal has been proved, divided into three seams. The quality appears to be much the same as that of the Warora coal.

5. Outliers near Khair and Arjuna.—Before proceeding to the description of the main Gondwána area in the Godávari valley, it is desirable briefly to notice some outliers to the west of the northern portion. Near the village of Khair, about 25 miles west of Chánda a considerable area of sandstone is found extending for about 5 miles up a valley between low hills of Deccan trap. Similar sandstone, greatly hardened, is again seen to the south, in the Yedurba stream, which is chiefly supplied by a copious hot spring close to Khair. Two other small outcrops separated by overlying trap are met with about 2 miles further to the south-west near the small village of Kasara, and a larger tract of irregular form, about 4½ miles from east to west and 3½ from north to south, occurs still further to the south-west, around the village of Arjuna, 9 miles south-west of Khair. All these outcrops are covered by trap to the north-west. The beds are very ill seen, but appear to rest on Vindhyan limestones to the east and south.

In places the beds of these outcrops are so greatly indurated that it was at first considered doubtful whether they could be referred to any known formation. This is especially the case with the rocks on the Yedurba stream and near Arjuna. The beds in the valley north-west of Khair have, however, the usual characters of Kámthis, and the discovery by Mr. Hughes of Tálchirs at the southern extremity of the Arjuna outcrop has shewn that all the rocks must belong to the Gondwána series. No exposure of typical Barákars has been detected, but the occurrence of this group is highly probable, and should coal be required in the neighbourhood, the exploration by boring of these areas near Khair will become necessary.

6. Wardha-Pranhita-Godavari basin.—*a. Wardha or Chánda coalfield.*—The large area of Gondwána rocks in Chánda and South-East Berar has received much attention of late years on account of the exertions made to procure from it a supply of coal for parts of the Great Indian Peninsula Railway. It is the north-western extremity of an immense tract of Gondwána rocks extending for about 285 miles from north-west to south-east, and with a maximum

breadth of about 35. This north-western portion having been carefully examined,[1] deserves a notice apart from the large but less thoroughly known region on the Pránhita and Godávari. The Chánda and Berar area derives its name from the river Wardha, which traverses it throughout, and forms its southern boundary, an artificial but convenient limit, at the point where that river, after running south-east or south for many miles, turns eastward and runs for about 20 miles with a general direction a little north of east till it joins the Wain Ganga. The Gondwána area is at this spot much narrower than it is to the north and to the south, being only about 14 miles broad from east to west.

The tract to the northward of this artificial boundary is about 70 miles in length from north-west to south-east, and nearly 30 broad where widest; extending to the north west to within 15 miles of Hinganghát: the area is about 1,600 square miles. The field may be considered as a trough lying between two great parallel faults which run from north-west to south-east, one forming the north-eastern boundary of the field from end to end, whilst the other only forms the actual boundary where the field is broadest about Wún and Chánda; the latter dies out to the south-east and disappears to the north-west beneath the trap. The Gondwána rocks, where most developed in the neighbourhood of Chánda, exhibit an anticlinal fold, much nearer to their south-western than to their north-eastern limit, and they dip on each side of this fold towards the boundary. Along the axis of the anticlinal, Vindhyan beds crop out in places, and to the northward divide the Gondwána area into two arms, each running north-west along one of the boundary faults till the whole is covered up by the trap. To the south, as already mentioned, the south-western boundary fault appears to die out and the area assumes the normal form of a mass of rocks, dipping steadily at a low angle to east-north-east, and abruptly cut off in that direction. The area to the south-west of the Gondwána tract is chiefly composed of shales and limestones belonging to the lower Vindhyan series (Pem shales and limestone), and inliers of these rocks are exposed here and there within the limits of the Wardha field. To the north-east and east metamorphic rocks are chiefly to be found, except for about 20 miles north-east of Chánda, where the Gondwána rocks abut against Vindhyan quartzites. Every here and there, however, along the north-eastern boundary fault, masses of Vindhyan quartzite or limestone are found, some of them apparently faulted on both sides to the westward

[1] The account is taken from a description by Mr. Hughes, Mem. G. S. I., XIII, pp. 1–145.

against the Gondwána beds, to the eastward against the metamorphics. The southern boundary of the Wardha field, as already mentioned, is artificial; to the north-west all the older formations, metamorphic, Vindhyan, and Gondwána, disappear beneath the overlying Deccan trap and the infratrappean Lametas.

The groups exposed in the Wardha field are the following:—

Upper Gondwána—Kota-Maleri	. . . . . .	about 1,500
Lower Gondwána.	Kámthi	2,500 to 3,000
	Barákar	250
	Tálchir	? 500

The Tálchirs occupy a large area, altogether amounting to about 250 square miles, and must be of considerable thickness. Immediately west of the town of Chánda they cover a tract of country extending more than 20 miles from north to south by 14 broad, part of the area, however, being concealed by river alluvium. They also stretch for about 15 miles along the south-western edge of the Wardha field, in the Nizam's territory, south of Rajúr, and they are found forming a narrow fringe on the north-eastern edge of the western arm of the field north-west of Wún.

The mineral character of the Tálchirs is, as a rule, precisely the same as elsewhere. The upper beds are buff sandstones, often with a greenish tinge, and a tendency to break up into polygonal fragments. These sandstones pass downwards into greenish-grey (olive) silty shales, with or without sandy layers, and in these shales, especially towards the base, boulders are common. In one locality, at Irai, on the banks of the Pen Ganga (Pem or Pyne or Pain Gunga) river, not quite a mile above its confluence with the Wardha, Mr. Fedden had the good fortune to discover[1] boulders which exhibited polishing and grooving on their surface, whilst the underlying rock, consisting of Vindhyan limestone, was extensively scored, grooved, and polished, the striæ running in long parallel lines with a north east by north direction. Some flexible sandstone (quartz grains in an argillaceous matrix) has also been found in the Tálchir beds south of the Pen Ganga.

The Barákars are very thin, nowhere exceeding 250 feet in thickness, and they are often less than this. Their general descending section is—

1. A very thick seam of coal and carbonaceous shale
2. Sandstones and shales.
3. A few thin carbonaceous beds.
4. Sandstones and shales.

[1] Mem. G. S. I., IX, p. (234): Rec. G. S. I., VIII, p. 16.

The sandstones alone being, as a rule, seen at the surface; they are usually either fine-grained, light-grey beds, sometimes with specks of ferruginous quartz, iron pyrites, or carbonaceous matter, or else they consist of somewhat coarser beds, white, grey, or light brown in colour, containing little calcareous nodules, which weather out into small excrescences on the surface.

In some places sandstone belonging to the Barákars rests upon the thick coal seam, but over a very considerable area Kámthis appear immediately to overlie it. This seam is an irregular mixture of coal and carbonaceous shale, the proportions of the two varying in almost every one of the numerous bore holes by which it has been proved. As a rule, the greater portion consists of coal of rather inferior quality, some bands, however, being sufficiently good for steam purposes, while all might be used as fuel; the quantity of ash is generally large, varying from 14 to over 20 per cent. The thickness of the combined seam of coal and shale sometimes amounts to as much as 90 feet, but is more often between 35 and 50. Some thin seams, none of which are known to exceed 2 feet in thickness, are also found at a lower horizon.

The Barákars are most irregularly distributed in the Wardha field, being overlapped throughout a large area by the Kámthis. Owing to the mineral value of the Barákars, their extension has been carefully determined by boring. They appear in one spot about 6 miles north of Warora, but coal has not been proved here. It has, however, been found to underlie the alluvial ground near Warora, where a colliery has been established, and a large quantity of coal extracted. Barákars also occur, and coal has been found, in the bed of the Wardha near Aikona, 6 miles west-north-west of Warora. The dip here is south-west, and the coal doubtless extends under the trap to the southward.

The next tract of Barákars to the southward is along the arm of the field already described as extending north-west of Wún. Here the Barákars form a straight outcrop, about a mile broad, dipping south-west, and they have been traced for 8 miles from north-west to south-east on the surface, and 3 miles farther to the south-east by boring. They may be continuous with the area further east and south-east, extending for about 20 miles from west of Bhandak to the Pen Ganga west by south of Chánda, and containing the thick coal of Telwása, Ghúgús, &c. This belt of Barákars extends along the western edge of the Tálchir area west of Chánda, until, to the southward, the Barákars are overlapped by the Kámthis. The Barákars reappear, however, south-east of the Tálchir anticlinal, about Ballarpúr and Sásti, and are represented, though apparently but feebly, at Chánda itself, where the upper portion, including the

thick coal, is absent. They are completely overlapped by the Kámthis north of Chánda. The great tract of Kámthis east and south-east of Chánda has not been sufficiently explored by boring to ascertain whether Barákars underlie it or not.

One more tract of Barákar rocks extends for 12 miles along the south-western margin of the field from Sirsi, 7 miles south of Rajúr, to Antargáon on the Wardha, where that river turns to the eastward. South of Rajúr the Kámthis completely overlap the Barákars as far as Sirsi. Some coal occurs, but the thick seam has not been traced.

The Kámthis occupy all the eastern and north-eastern portion of the field, as well as a large tract in the north-western portion around Wún, and more than two-thirds of the whole surface is composed of them. They are unconformable to the Barákars as already mentioned, and overlap them in many places, resting generally upon the Tálchirs, but occasionally on the Vindhyans. Their mineral character is the same as near Nágpúr, except that they comprise in places beds of red, yellow, and grey clay.

At the base of the Kámthi group, the principal beds are coarse-grained, porous, friable sandstones, slightly yellow, reddish-brown, or grey in colour. The porosity of these beds generally enables them to be distinguished from the sandstones of the underlying Barákar group, even when the Kámthi beds are deficient in the ferruginous bands so frequently associated with them. These sandstones average 400 to 500 feet in thickness; the town of Chánda is built upon them, and they are well seen on the banks of the Wardha below the coal pit at Ghúgús, west of Chánda. Clays and shales are occasionally interstratified, but neither the argillaceous beds nor the hard irregular ferruginous bands are invariably found.

Above these lower sandstones, there is, in places, but not universally, a considerable thickness of the typical Kámthi beds, consisting of compact grits, breaking with a conchoidal fracture, and ringing under the hammer, fine-grained or coarse sandstones with red blotches and streaks upon a whitish, yellow, or brownish-red surface, very fine-grained compact homogeneous sandstones, having an argillaceous appearance, but apparently free from clay, buff in colour beneath the surface, but deep red when exposed, and ferruginous sandstones and conglomerates containing small quartz pebbles. On this horizon in the northern extremity of the field, and about 600 or 700 feet above the base of the group, are the beds of Mángli, from which the *Brachyops*, *Estheriæ*, and other fossils mentioned in the fifth chapter were obtained, and at approximately the same position in the group, about 16 miles due west of Chánda, around

Kawársa and Panwat, some fossiliferous beds were found, from which besides a form of *Estheria mangaliensis, Phyllotheca indica, Glossopteris indica, G. browniana,* and fragments of *Schizoneura* have been recognised.[1] In some shales near Chánda, also near the base of the Kámthis, fine fronds of *Glossopteris* have been found, and in another place some impressions referred to *Actinopteris;* but, as a rule, fossils are of rare occurrence in the Kámthi group of the Wardha coal-field.

The upper portion of the Kámthis consists of a great thickness of coarse sandstones, grits and conglomerates, with occasional shales and clays. The beds are usually more or less impregnated with iron, and sometimes are highly ferruginous: manganese is also of common occurrence, and in some red clays at Malágarh hill, west of Kawársa, botryoidal masses containing no less than 44·6 per cent. of oxide of manganese were found.

The upper beds of the group are usually poorly exposed; they occupy the wild forest country east and north-east of Chánda, sometimes rising into low hills, but more often covered and concealed by the thick sands and clays which result from their decomposition. A few outcrops are seen south of Wún, and in the Wardha below Chánda, but no connected section of the rocks is anywhere exposed. It is consequently impossible to estimate the thickness of the Kámthi group with accuracy.

The Kota-Maleri beds are only found north of the Wardha in a small triangular tract around the village of Dhába in the south-east corner of the Wardha field. This patch is the northern extremity of the great area which extends to Maleri and Kota, and thence to the south-east far beyond Sironcha. The greater part of the area is covered with alluvium, but on the banks of the Wardha, about Porsa, Enkatpúr, and Sakmúr, sections of the characteristic sandstones and clays of the group are seen. The Kota-Maleri group appears to be unconformable to the Kámthi beds; but the relations are ill seen in the small area north of the Wardha river.

No basaltic dykes are known in any part of the Wardha coal-field, nor have any hitherto been noticed elsewhere in the Gondwána area of the Godávari valley. This absence of all evidence of volcanic outbursts is very remarkable, because the Gondwána rocks disappear beneath the Deccan traps to the westward, and an outlier of the same formation is found at the south-eastern extremity of the whole tract near Rájámahendri.

Wardha-Pranhita-Godavari basin.—*b. Central portion.*—From the spot where the Wardha runs eastward to join the Wain Ganga, just

[1] Mem. G. S. I., XIII, p. 70.

above the so-called third Godávari barrier on the Pránhita, a stream formed by the confluence of the two other rivers, to within a few miles of Dúmagúdem (Doomagoodiam), at the first Godávari barrier, is a distance in a direct line of about 140 miles. A broad belt of Gondwána sandstones extends throughout, but the river does not keep within the boundary of the sedimentary rocks. The Pránhita, throughout the greater portion of its course, runs to the eastward of the sandstone area, and the main stream of the Godávari, which enters the sandstone some 30 miles above the junction with the Pránhita, re-enters the older rocks about 25 miles below the junction, just above the confluence of the Indrávati (Indrawutty) river. From this spot the Godávari runs through transition beds and metamorphics for nearly 20 miles, forming the portion of its course known as the second barrier: the river then re-enters the newer sandstone area, through which it runs till just above the first barrier at Dúmagúdem. The Gondwána rocks, however, nowhere extend far to the east of the Godávari, quartzites appearing below the second barrier at a short distance from the river bank.

This large area of sandstone is as yet but imperfectly known; the country is very wild and, for the most part, covered with forest, and the surface is much concealed by alluvial deposits.[1] From the Wardha coal-field the present tract is separated by the Wardha river, the separation being, as already explained, merely one of convenience, at a spot where the field of sandstone is unusually narrow. To the south-east the limit is still better marked, there being a great contraction in the breadth of the Gondwána area at Palúncha, 15 miles west-south-west of Bhadráchelam, where the sandstone tract is only 6 miles across, while to the north-west it is between 30 and 40 miles broad, and to the south-east seldom less than 25, and in places considerably more. The north-east and south-west boundaries of the intervening Gondwána area are nearly straight, and in general present an approximate parallelism.

A short distance south of the Wardha the sandstone area becomes much broader, and the western boundary thence to the Godávari is formed partly by Vindhyan (or Kadapah ?) rocks and in part by the overlying Deccan trap, the sedimentary beds being exposed in one locality in a valley between ranges of trap hills. South of the Godávari the trap boundary leaves the Gondwána area and runs to the south-west, and by far the greater part of the Gondwána boundaries, both to the

[1] It is now under examination, and much additional knowledge of its structure has been obtained very recently. The following description is chiefly taken from manuscript reports by Messrs. King and Hughes.

north-east and the south-west, consist of Vindhyan or transition rocks. Throughout a considerable portion of the Gondwána region there is a low dip of the strata to the north-east, so that, as a rule, the lower beds are exposed along the south-western boundary, and high beds abut against the north-eastern margin of the field.

The greater portion of the area consists of coarse sandstone, more or less conglomeratic. The groups known to be represented are the Kota-Maleri beds, with some overlying sandstones (Chikiála group) which closely resemble a higher group in the Rájámahendri country, the Kámthi, Barákar, and Tálchir groups of the lower Gondwána series. Both of the latter, so far as is known, are confined to small and isolated tracts.

Tálchirs have hitherto been found in a few places only. Of these the most northern is just north of Náogáon about 12 miles south-west of Sirpúr. The area occupied is very small. The same beds, however, resting upon Vindhyans, stretch along the western boundary of the Gondwána area from Kairgura, south of Jangáon and 26 miles south-west of Sirpúr to the Godávari near Náspur, 22 miles west of Chinúr, and probably for some distance south of the river. The Tálchirs are again found close to Chinúr, overlying an inlier of Vindhyan rocks, both formations being brought up within the Gondwána area, in all probability, by a north-west and south-east fault. Throughout these exposures the typical Tálchir shales are rare, the group consisting chiefly of sandstone; but the boulder bed is well developed, the boulders consisting partly of Vindhyan, partly of metamorphic rock. In the country south-west of the Godávari the Tálchirs have been noticed around Sallawai (Sullavoy of the map), about 16 miles north by east of the great Pakhal tank and 36 miles north-east of Wárangal. Lastly, they are found in the Tál river, close to its junction with the Godávari, 16 miles north of Dúmagúdem, and extend for some distance to the south and south-east along the edge of the Gondwána area.

Barákars occur on the Wardha near Antargáon, where they form a continuation of the Chánda and Sásti coal-field, but they are covered up and overlapped by Kámthis to the south. They reappear about 10 miles farther south near Náogáon, but only occupy two or three square miles, and no coal has been hitherto detected in them. A more important outcrop extends from Kairgura, south of Jangáon, for about 25 miles in a south-east direction to the village of Aknapali. The breadth of the outcrop is not more than a mile, and the beds are ill seen as a rule, but sections of the typical sandstones occur in the streams, and a coal seam has been found in three places, the thickness

exposed varying from 5 to 15 feet. It is by no means improbable that this seam is continuous throughout the Barákar area. The quality of the coal appears to be fair, but hitherto the seam has not been cut into.

No Barákars have been detected resting upon the Tálchirs between Aknapali and the Godávari, a distance of about 16 miles, but it is not impossible that borings may shew the existence of the coal-bearing rocks. Near Chinúr and Sandrápali, however, beds of unmistakeable Barákar character rest above the Tálchirs, and fragments of coal found in the Godávari, below Sandrápali, probably indicate the existence of a seam concealed by the sand in the bed of the river. Barákars are again seen in the Godávari at the mouth of the Tál river near Dúmagúdem, and they extend thence for 4 miles to the south, whilst to the north they and the underlying Tálchirs appear either to be overlapped by the Kámthi beds or cut off by a fault. In this neighbourhood the Barákars are best seen about Lingála on the left bank of the Godávari. They have rather a high dip, and reappear on the opposite river bank in the Nizam's territories. Some coal occurs, but the thickest seam found measures only 2 feet.

Throughout the large tract south-west of the Godávari between Chinúr and Dúmagúdem, no Barákars have been found away from the river's bank, although they very probably are represented by some coarse sandstones at Sallawai resting upon the Tálchirs already mentioned, and an outcrop must exist at Alapali on the Kinerswámi (Kinarsani) stream, 30 miles west of Dúmagúdem, as numerous fragments of coal are found in the bed of the stream.

The Kámthi beds occupy a great portion of the area, and appear to stretch uninterruptedly from end to end. They must be very thick [2]; the greater portion of them consist, however, of brown ferruginous sandstones without any especial characteristic, and it is, as a rule, only towards the base that beds of peculiar character occur. In this position the porous, coarse-grained, friable sandstones, so characteristic of the lowest portion of the group in the Wardha field, usually occur, and it is, as a rule, easy to define the lower limit of the Kámthis and to separate them from the underlying groups; but their upper margin is far less easily determined with accuracy. The compact red and buff shales, and the typical grits breaking with a conchoidal fracture are less common south of the Wardha than to the northward. South of the Godávari,

[1] See Rec. G. S. I., IV, pp. 49, 108.

[2] The estimate of 17,000 feet, mentioned in the Rec. G. S. I., X, p. 28, has since been found to be excessive, and due, apparently, to repetition by faulting.

in the neighbourhood of the Manair (Maner) river, and south of Madápúr near Sironcha, there is a great series of sandstones, mostly fine-grained, soft, yellow, salmon-red and reddish-brown in colour, and amongst them is a fine-grained salmon-red sandstone with fragments of purple Vindhyan shale. These beds appear to underlie the massive Kámthi sandstone, and are by Mr. King called the Tárcherla sandstones, from the name of a village on the Manair river. It is, however, by no means clear that the Tárcherla sandstones are really inferior in position to the Kámthis.

The upper Gondwánas occupy all the north-eastern side of the field from the Wardha to below the second barrier on the Godávari, a distance of nearly 100 miles, and between the Wardha and the Godávari near Chinúr these beds occupy a much larger tract than the lower Gondwánas, the upper Gondwána outcrop near Maleri, north-west of Sironcha, being 25 miles across. Owing to the difficulty already noticed, of distinguishing between the upper Gondwána beds and the Kámthis, the limit of the two series is still somewhat doubtful, and this is even more the case south of the junction between the Pránhita and Godávari than to the northward. It remains to be seen how far the upper Gondwánas can be traced to the south-east; they have hitherto not been recognised in the neighbourhood of Dúmagúdem.

In the extreme north-west of the present area, near Jangáon, the upper Gondwána beds completely overlap the lower so as to rest on the underlying Vindhyan rocks, and to occupy the whole breadth of the basin for a short distance. There is nevertheless, as usual, a very close accordance in dip and strike between the upper and lower Gondwána beds, both having in general the same north-east dip, and no marked break can be detected between them.

These beds have not yet been sufficiently thoroughly surveyed to enable their relations to be perfectly understood, but a sub-division into two groups has been indicated by Messrs. King and Hughes, and the former appears disposed to separate a third lower division. The evidence, however, is at present insufficient to prove the distinction, although it is by no means improbable that further sub-division will be necessary.

The Kota-Maleri beds, which have been already described in the general account of the Gondwána system, form the most conspicuous and important group of the series. They occupy the Jangáon valley west-south-west of Sirpúr and a large area on the Wardha, near Sirpúr, and they extend across the country around Maleri (a very small village near the road from Chánda to Sironcha) to the Pránhita, where they are seen at Kota and elsewhere for several miles north of Sironcha.

Hence they extend to the Godávari near Aserali, a few miles above the junction of the Indrávati, and thence along the south-west flank of the quartzite hills on the right bank of the Godávari between the mouth of the Indrávati and Yenchapali (Inchapilly), whilst beds of similar mineral character are exposed in the Godávari about 20 miles further down, below the second barrier which terminates at Yenchapali itself.

The Maleri red clays occupy a large tract in the north-western portion of the Kota-Maleri area, around Jangáon, Bibra, and Maleri. The Kota limestone is rather higher in the series, and has been traced at intervals for 36 miles to the north-west, as far as the neighbourhood of Itial and Bibra, where these beds crop out in a low range of hills, and for about 20 miles to the south-east, the strike being from north-west to south-east, and the dip, like that of the associated beds, to the north-east. In the upper portion of the group, above the limestones of Kota, clays are less developed, and the rocks consist chiefly of sandstone. Besides the main tract of Kota-Maleri beds, there is a detached area on the Godávari west of Chinúr and Sandrápali, apparently brought down by the north-west south-east fault to which the outcrop of Vindhyan quartzites, Tálchirs and Damudas, on the eastern side of the upper Gondwána outcrop, must be attributed.

The suggested separation of the beds at the base of the Kota-Maleri group, on account of some differences in mineral character, and the presence of the two plants belonging to the Rájmahál flora has already been noticed in the sixth chapter of this work. It was shewn that, although the separation of the Sironcha sandstones may be possible, the evidence at present available is quite insufficient to justify the distinction. The separate classification of the uppermost portion of the Gondwána system near Sironcha, under the name of Chikiála group, appears founded on better evidence, although no fossils have hitherto been discovered in the higher beds. The Chikiála beds have been traced for several miles, along the north-eastern boundary of the Gondwána area, in the neighbourhood of Chikiála, north of Sironcha, their extension to the north-west in the direction of the Wardha being probable. To the south-east they have not been traced. Throughout their range they are highly ferruginous, and they furnish the ore used by the iron smelters of the country.

On the southern edge of the Jangáon valley, near the village of Balanpur, and close to the spot where the westernmost extension of the Gondwána beds is covered up by the trap, some soft yellow sandstone occurs, containing carbonaceous markings, and overlying about 5 feet of

shale with thin irregular strings of jet coal, precisely like the Jabalpur coal of the Sátpúra region in character. These beds overlie the Kota-Maleris. Some other beds in the same neighbourhood resemble in character the ferruginous Chikiála sandstone. It is probable that the Balanpur beds belong to a higher group than the Kota-Maleris, and the marked resemblance in the character of the coal tends to suggest that the former may belong to the Jabalpur group, whilst on the other hand there is a possible connection with the Chikiála beds, and consequently the Chikiála and Jabalpur groups may be identical, but the evidence is insufficient to do more than suggest the possibility of this.

Wardha-Pranhita-Godavari basin.—*c. South-eastern extension.*—The south-eastern portion of the Godávari basin forms a well-defined area, only joined to the remaining tract by the narrow neck already mentioned, south-west of Bhadrachelam. The present area comprises the most southerly exposure of lower Gondwána rocks (Damúda and Tálchir) known to occur in India, and their importance, as offering some hope of the discovery of coal within the Madras Presidency, has led to their receiving more attention than similar beds in the region to the north-west.[1]

The tract in question is irregularly shaped. It consists principally of a belt of country running from north-west to south-east for above 50 miles, and in general about 25 miles broad, but expanding towards the south-east into a much broader area, which extends from the Godávari above Rájámahendri for a distance of 60 miles to the south-west, ending within 20 miles of the Krishna (Kistna) river at Bezwáda. This south-eastern portion, however, consisting of upper Gondwána beds alone, belongs to a different section, the outcrops of the eastern coast, and it will consequently be described separately. On the northern portion of the basin, too, there is an expansion to the eastward, forming the coal-field of Madaváram below Bhadrachelam.

The boundaries appear to be for the most part natural. So far as is known, there is no abrupt junction with the older rocks extending for any great distance. Throughout the greater part of the boundary the Gondwána beds rest upon metamorphics; to the south-east, near Ellore, they disappear beneath Deccan trap, tertiary sandstones, and the alluvium of the Godávari and Krishna (Kistna) deltas.

The formations met with in the north-western portion of the area are Tálchirs, Barákars, and Kámthis. The Tálchirs are only seen on the margin of the tract in three localities, in all of which they underlie Barákar beds.

[1] For fuller description, see Rec. G. S. I., IV, pp. 49, 59, 82, 107; V, pp. 23, 112; VI, p. 57; X, pp. 55, &c. Some details are also taken from MS. reports by Mr. King, who is the author of several of the printed papers quoted.

The first of these is on the border of the Madaváram coal-field, east of Bhadrachelam. Here Tálchirs are seen to occur at or outside the northern boundary in three patches, none of which are of any extent, and the largest exposure, which is about 1½ miles long, is nearly, if not entirely, surrounded by metamorphics, and outside the general sandstone boundary. The same rocks are also seen south of the Godávari, at the south-east corner of the Madaváram coal-field. The only other spot where the Tálchirs appear within the boundary is about 25 miles south-west by a little south of Bhadrachelam, on the south-west boundary of the Gondwána area, near a hill called Kanigheri. But several Tálchir outliers are met with about Dúmagúdem and Bhadrachelam outside the edge of the Gondwána area; three at least appear in the bed of the Godávari, below Dúmagúdem; two are very small and almost confined to the bed of the river; but the third, which occurs about 6 miles below Dúmagúdem, extends for 5 or 6 miles to the eastward from the river. Another is met with on the Kinarswámi stream, 5 miles west-south-west of Bhadrachelam, but it is only about 2½ miles across. The irregularity of the distribution of these patches of Tálchirs, and the absence of the formation, as a rule, at the base of the Barákars, appear to shew that the latter are more unconformable to the former than they usually are elsewhere.

The Barákars are found in three localities. The first of these is the Madaváram coal-field on the Godávari, below Bhadrachelam. This is a tract of somewhat irregular form, 7 miles across from east to west, and 5 miles, where broadest, from north to south; it is traversed throughout by the Godávari from west to east, and the area is about 24 square miles. The rocks are very poorly seen, the ground being much covered by alluvial deposits, but from the few dips observed, it appears probable that some of the boundaries are faulted. The portion of this tract north of the river has been explored by boring, and some coal was found, but the quality was inferior, and the seams thin and much mixed with shale, whilst the beds were found to vary much in thickness and composition within a short distance. The tract south of the river has not been thoroughly examined. The sandstones and shales preserve the usual character.

The second tract of Barákars is the Beddadanol field, which lies about 35 miles south-east of Bhadrachelam, and the same distance north by east of Ellore. The large village of Ashraopettah is 5 miles to the westward. This small field is 5 miles from north to south by about 2 broad, the Barákars being completely overlapped both to the north and to the south by the Kámthis; the former rest on metamorphics to the eastward, no Tálchirs occurring, and to disappear

beneath Kámthis to the west. The Barákar area is about 5½ square miles. The only rocks seen at the surface are coarse felspathic sandstones, grey, white, or buff in colour, with ferruginous concretions. At least 600 feet of Barákar rocks would appear to occur, the dip being usually low, from 2° to 10°; some coal has been discovered by boring, but the quality is inferior.

The third tract lies at the spot near Kanigheri already mentioned, 25 miles south-west by south of Bhadrachelam and 15 miles south of Paluncha; it is 6 miles long from north-west to south-east and 2 miles across. The Barákars rest partly on Tálchirs, partly on metamorphics to the westward; they look as if cut off by a fault to the north-west, whilst to the east they are covered up by Kámthis.

The greater portion of the area under description consists of Kámthi beds. Further examination may shew that some strata now assigned to the Kámthis must be referred to a higher formation, but there can be but little doubt of the relations of those rocks which occupy the surface throughout the greater portion of the tract. They are chiefly coarse felspathic sandstones and grits, generally loose textured, and of various shades of brown, often conglomeratic and frequently traversed by ferruginous bands. But at places white, lilac, and red argillaceous shales occur, and in some instances, chiefly along the south-west boundary, the typical yellow compact shale weathering red is seen. In the interior of the tract the Kámthis form large masses of hills, nearly flat-topped, the beds rolling about with very low dips. It appears probable that there is great unconformity between the Kámthis and Barákars, and the extremely local distribution of the latter may be due to their having been largely denuded before the deposition of the Kámthi beds. At the same time there is a possibility that the Barákars were originally deposited in isolated patches.

The Rájmahál beds extend along the south-eastern margin of the Gondwána area, as already mentioned. They will be described separately in the next section.

7. Kamaram coal-field.—These are two small outliers, a few miles outside the south-western boundary of the Pránhita-Godávari sandstone area, and situated nearly 40 miles east by a little north from Warangal in the Hyderabad territory, and about 12 miles east-north-east of Pákhal tank. The name of the coal-fields is derived from a small village lying at the southern extremity of the smaller field and 6 miles to the south-south-east of the larger one.[1]

[1] For description by Mr. King, see Rec. G. S. I., V, p. 50. The village is called Kamawaram on the map, and this is probably the correct name, corrupted into Kamáram by the lower classes of natives.

The whole length of the principal field is about 6 miles and its breadth about a mile; it consists of Tálchir, Barákar, and Kámthi rocks, all dipping at a considerable angle to the south-west, and cut off, nearly in a straight line, by one of the usual abrupt boundaries running from north-west to south-east and parallel to the boundaries of the main Godávari area to the north-east. The Tálchirs extend round the north-eastern edge of the field; along the south-western, for part of the distance at least, the Barákars and Kámthis abut against the old Kadapah rocks, by which the field is surrounded. The Tálchirs are the usual fine olive shales, with boulders in places. The Barákars extend for nearly a mile and a half; their breadth, however, is but slight, as only about 300 feet of them appear to occur. They rest upon the denuded edges of the Tálchirs in places, the unconformity between the two groups being clearly shewn. They consist of grey argillaceous sandstone, with beds of coal, two of the coal-seams being of fair quality, and measuring, the one 9 feet, the other 6 feet, in thickness. The small area of the field and the high dip, as well as the distance from road or water carriage, are serious drawbacks. The Kámthis are poorly developed, being about 1,000 feet thick, but occupy only a very small area. They reappear in the smaller outlier at the village of Kamáram. This small basin is only a mile and a half long by half a mile broad, and is of no importance.

8. **Singareni coal-field.**—This is a small outlier,[1] about 30 miles south-west of the main field in the Godávari valley, and 25 miles north by a little east of Khamamet (Kamamet or Kummummett). The present field derives its name from the large village of Singareni, lying about 4 miles west of the southern portion. It is situated in the Kandikonda talúk of the Khamamet Sircar belonging to Hyderabad, and is within the drainage area of the Krishna (Kistna) river.

The Singareni coal-field is irregular in form, extending for about 12 miles from north-north-west to south-south-east, and from one to a little over 2 miles broad. The area is about 19 square miles. The groups exposed are Tálchirs, Barákars, and Kámthis.

The Tálchirs occupy the northern portion of the field only, and consist of the usual fine olive shales, boulders not being common, though some are found. The Barákars are distinctly unconformable to the Tálchirs, and the irregular distribution of the Kámthis and Barákars appears probably also due to unconformity, the former overlapping the latter, and resting sometimes on the Tálchirs, and elsewhere on the old Kadapah rocks or on gneiss.

[1] For description by Mr. W. King, see Rec. G. S. I., V, p. 65.

The Barákars are found in several detached areas, separated from each other by intervening masses of Kámthis. There are two principal areas, one about the middle of the field, and another along its western edge near the southern extremity. In the former a seam of coal was found at the surface, and additional seams, one of them said to be 21 feet thick, have been detected by boring.

VII.—East Coast region.—The representatives of the Gondwána series, which are scattered along the eastern coast of the Peninsula, differ from all those in the interior of the country, in being either chiefly or entirely composed of the Rájmahál group, which, to judge from the remaining outcrops, may once have extended from Rájmahál to Trichinopoly, if not farther south. A portion of the outcrops appear of rather later date than the others, but the difference is not great. Singularly enough, the characteristic flora of the Rájmahál group has not hitherto been found elsewhere, although a few Rájmahál species are found in the Umia beds of Cutch, the Jabalpur group of Central India, and the Kota-Maleri beds near Sironcha,—all of which are believed to be of later date.

Another peculiarity by which the Gondwána outcrops of the east coast are distinguished from all others in India, except the beds of Cutch, is their association with rocks containing marine jurassic fossils. The present section consequently serves as a natural introduction to the account of the Cutch jurassic formations, which will occupy the next chapter.

The localities at which the Gondwána formations are known to occur along the eastern edge of the Peninsula are the following, beginning at the north :—

1. Rájmahál hills (already described).
2. Athgar basin.
3. Outcrops east of Rájámahendri.
4. Ellore area (part of Godávari-Gondwána basin).
5. Ongole outcrops.
6. Sripermatúr outcrops.
7. Trichinopoly outcrops.

The Rájmahál hills have already been described; the other tracts require but brief notice. It is possible that further examination of the country south of Trichinopoly may shew the existence of other representatives of the Rájmahál group, and others, again, may occur between Rájámahendri and Cuttack.

The association of marine fossils with the Rájmahál group along the east coast appears to indicate that these beds were not deposited, like

2. **Athgar (Atgurh or Atgarh) basin.**—This is a tract of sandstone, close to the town of Cuttack, on the western edge of the alluvial plain, which extends to the sea-coast.[1] The rocks are very flat and greatly concealed by laterite, which covers them completely to the eastward, whilst a considerable portion of the area is covered with singularly thick, almost impenetrable, bamboo jungle. The name is derived from a zamindári, or estate, in which the portion of the tract first examined is situated.

The area occupied by the sandstones slightly approaches a rectangle in form (the boundaries being, however, very irregular); it is about 20 miles long from north to south, and about 18, where broadest, from east to west. Its boundary to the westward is formed partly by metamorphic rocks, on which the sandstones appear to rest, but chiefly by a plain of [illegible]m: east and south the sandstones disappear beneath [illegible] ttle farther dips also beneath the alluvial plain. [illegible]

The roc[illegible] conglomerates containing pebbles of qu[illegible], and in one case black carbonaceous sh[illegible] ound at Naráj, on the Máhánadi, west of C[illegible], an[illegible] e the presence of Barákar beds, but no Damúda fossils have been found associated with it. The relations of the remaining portion of the rocks were obscure until recently, and it was thought that they probably represented the Kámthi (or supposed Mahádeva) beds of the Tálchir coal-field.

Quite lately, however, the following characteristic Rájmahál plants have been found in the Athgar tract[2]: *Alethopteris indica, Asplenites macrocarpus, Gleichenites bindrabunensis*, and *Palissya indica*; and there can no longer be any doubt but that the Athgar area is one of the

[1] Mem. G. S. I., I, pp. 68, 264; Rec. G. S. I., V, p. 59; X, p. 63. The last-quoted account by Mr. Ball contains a much more complete description of the beds than the earlier notices.

[2] By Mr. Ball. The identifications are by Dr. Feistmantel.

detached patches of upper Gondwána sandstone extending along the eastern coast of the Peninsula.

The sandstones, &c., have a very low dip from west to east, or rather to the south-east, and the beds to the westward appear to be the lowest. These are chiefly composed of coarse conglomerate, which forms low scarps facing the westward. The actual base is nowhere seen. The carbonaceous shale of Naráj appears to owe its appearance at the surface to the elevation caused by a basaltic dyke, which traverses the beds, and is the only known case of their being affected by volcanic action. The age of this basalt dyke is unknown; it is far distant from any known outburst of either Rájmahál or Deccan age, and as no trap dykes occur in the Tálchir country, it is not probable that Orissa is within the area affected by the latter series of volcanic eruptions.

3. Outcrops east of Rajamahendri.—The east coast from Ganjám to Vizagapatam has not been surveyed, but south-east of Vizagapatam, and between that town and Rájámahendri, several outcrops of Gondwána beds have been found.[1] These exposures are six in number, and all are very small, none exceeding 5 miles in length: all are on the edge of the alluvium.

The most eastwardly exposure is close to the coast, about 40 miles north-east of Coconada, where a narrow strip of coarse brown sandstone, about 2 miles long, is seen resting upon the edge of the gneiss hills of Sudi Konda. The next is a similar, but rather larger, outcrop, 8 miles to the south-west, near the village of Eedatum, where the bottom beds are hard, coarse, gritty sandstone, brown in colour, and often containing small pebbles. Half a mile to the south-west, near the village of Jilladypad, is a small ridge, 1½ miles long, surrounded by alluvium, and composed of brown sandy clay and sandstone. Four miles west by south of this again, at Innaparaz-polliam (or Innaparaz-Cotapilly), there is another low ridge, a couple of miles in length, similarly rising from the alluvium, with gneiss ridges to the north. This southern ridge consists of purple and brown sandstones, and conglomerates containing casts of marine fossils, amongst which *Trigonia ventricosa*[2] and *Trigonia smeei*, two of the most characteristic forms of the Umia beds of Cutch, have been recognised. Twelve miles east of this, again, similar beds crop out on the edge of the alluvium near Kirlumpudi, and occupy a rather larger area, extending nearly 3 miles from north to south by 2 miles broad,

[1] The details of these are from manuscript reports by Mr. King. The beds are briefly noticed: Rec. G. S. I., VII, p. 159.

[2] A woodcut of this species will be given in the next chapter. *T. smeei* is figured Pl. XII, fig. 11.

and 8 miles further east at Jagampet there is a sixth outcrop, more than 4 miles in length.

The only one of these outliers which has yielded fossils is that of Innaparaz. From the isolation of these patches, their relations to the Rájmahál beds near Ellore are difficult to trace, but they appear to represent the highest sub-division or Tripetty sandstones.

4. Ellore.—On the left bank of the Godávari, near Thalapúdi, about 10 miles above Rájámahendri and 25 miles west of the Jagampet outlier just mentioned, a well-marked belt of upper Gondwána beds commences, which extend from the Godávari to beyond Golapilli, west of Ellore, a distance of 60 miles. The width of this belt varies from 10 to 15 miles. There is a general dip to south-east or east-south-east at 5° to 10°, and the beds rest unconformably, throughout a considerable portion of their area, upon various members of the Kámthi group, but they overlap this group both to the east and west, and rest upon a sloping floor of gneiss, which has the appearance of a plane of marine denudation, formed after the deposition of the Kámthi rocks, as the latter rest upon a much more uneven surface of the metamorphic formations. This appearance of resting upon a surface which had been fashioned by denudation after the deposition of the lower Gondwána beds, quite agrees with the peculiar distribution of the Rájmahál group and its associates, which evidently were accumulated in a distinct area from that in which the Gondwána beds of the Godávari valley were deposited. To the south-east the upper Gondwána beds of the Ellore area disappear beneath the tertiary Cuddalore sandstones and the alluvial deposits of the Godávari delta, except west of Rájámahendri, where the Gondwánas are covered by outliers of the Deccan traps.

The rocks of the Ellore area[1] are peculiarly interesting, because they appear to contain representatives of groups higher than the Rájmahál, associated with beds in which the typical Rájmahál flora is well preserved. Mr. King, who has surveyed the rocks of the Godávari district, classes the upper Gondwána beds in three sub-divisions, thus distinguished in descending order, as already noticed in the sixth chapter :—

1. Tripetty sandstones.
2. Ragavapuram shales.
3. Golapilli sandstones.

The Golapilli sandstones consist of brown and red sandstones and conglomerates, which, near Golapilli, form a hard plateau capped by conglomerates and gravels, probably belonging to the tertiary Cuddalore

[1] For a description of these beds by Mr. King, see Rec. G. S. I., X, p. 56.

sandstones. In this plateau, near the village of Ravacherla, Mr. King found numerous plant fossils, including *Ptilophyllum acutifolium*, species of *Pterophyllum, Cycadites, Dictyozamites, Palissya, Alethopteris, Asplenites, Gleichenites*, &c., nearly all of which are found also in the Rájmahál group. These fossils occur in a fine yellowish-brown sandstone.

The Golapilli beds extend throughout the area from east of Golapilli to the neighbourhood of the Godávari.

Above the Golapilli beds, about the middle of the area, occur the Ragavapuram shales, with *Ammonites, Leda*, plants, &c., already noticed in the sixth chapter. These shales are traced for about 18 miles, intervening between the Golapilli sandstones and the Tripetty beds. The uppermost group, considered by Mr. King to represent the sandstones of the Innaparaz outlier with *Trigonia ventricosa* and *T. smeei*, extends across the whole tract from Golapilli to the Godávari.

5. Ongole.—The outcrops which have been found near Ongole are very numerous,[1] but owing to the manner in which the surface of the country near the coast is covered with laterite, lateritic gravel, and black soil, the rocks are ill exposed, and in many places can only be detected in well sections or excavations for tanks. The most northern exposure hitherto found in the country south of the Krishna river is close to the town of Guntoor; thence to Ongole there is a series of small tracts (five in all) along the edge of the coast alluvium. In these tracts shales and sandstone, very similar to those of Sripermatúr, are exposed. At the town of Guntoor, in well sections, grits and conglomerates are seen, resembling in lithological characters some of the Sripermatúr beds. About 6 miles to the south-east of the town, a long low ridge rises from the alluvium and extends about 14 miles from north-east to south-west, though only about 2 miles broad. This ridge consists of compact brown, reddish and purplish gritty sandstones, probably representing the Tripetty sandstones, and resting upon soft white shales, with ferruginous partings, doubtless identical with the beds of Sripermatúr and Ragavapuram.

The two most important outcrops south-west of Guntoor are those at Inkolu (Yinkolu), 26 miles north by east of Ongole, and at Vamevaram (Wamayavaram), 14 miles north by east of Ongole. In each case, the beds have been traced over 12 to 15 square miles of country. In the Inkolu outcrop, at the village of Budhavada (Boodhawadah), 3½ miles west by north of Inkolu, limestones and calcareous sandstones were found containing large numbers of oysters, besides *Ammonites, Patella, Pecten, Leda, Terebratula, Rhynconella*, and numerous other genera of mollusca.

[1] They have been described by their discoverers, Messrs. C. Æ. Oldham and Foote, in manuscript reports only. See also *ante*, p. 141; and Rec. G. S. I., II, p. 37.

The marine beds apparently are at a lower horizon than the sandy shales seen east of the village from which *Ptilophyllum*, *Dictyozamites*, and other plants were obtained. The plant beds contain a flora, apparently corresponding with that of the Ragavapuram shales, and comprising some species belonging to a higher horizon than the beds of Rájmahál itself and of Golapilli. The fossiliferous marine beds underlying the shales are the upper bands of a group of gritty sandstones, corresponding in position to the Golapilli beds, whilst above the supposed representatives of the Ragavapuram shales there is a hard sandstone, which forms a small plateau north-east of Budhavada, and which may very possibly represent the Tripetty group.

Near Vamevaram a much greater thickness of beds is exposed, consisting of shales, white, buff, and purplish in colour, with flaggy beds and thin bands of sandstone. In some of the higher bands an ammonite (perhaps identical with that met with at Ragavapuram in the Ellore area), a *Leda* (the Ragavapuram species), and impressions of other shells have been found.

Another outlier is found at Yendloor, 6 miles west by north of Ongole, and in some clays and sandy shales a few plant remains were discovered, one of which was a *Ptilophyllum*. Some indurated sandstone occurs at this spot, the relation of which to the shales is obscure.

South of Ongole several other small outcrops have been detected, the principal being west of the town of Kandakur (Cundacoor), 20 miles south-south-west of Ongole, and some highly fossiliferous shales are exposed in well sections at Kandakur itself. It is evident that the representatives of the upper Rájmahál beds here occupy a considerable area beneath the surface covering of laterite. These beds contain many of the usual Rájmahál plants. The most southern exposure of the rocks in this neighbourhood is about 15 miles south of Kandakur, and west of Ramapatnam.

6. Sripermatur outcrops.—These are a series of outcrops and outliers, the former along the edge of the metamorphic rocks and intervening between them and the laterite or alluvium of the coast, the latter scattered over the surface of the gneissic rocks. All consist of the Rájmahál group, and apparently of an upper sub-division of the formation, as near Ongole; they commence north-west of Madras and extend to the south-east, considerably beyond the Palar river.[1] None are known to exist more than about 50 miles from the coast.

By far the largest expanse of upper Gondwána beds in this neighbourhood lies west and north-west of Madras, in the neighbourhood

[1] For a complete description by Mr. Foote, see Mem. G. S. I., X, pp. 63-124.

of Sattavedu, Alikúr, and Pyanúr. The southern extremity of this tract is traversed by the Madras railway at a distance of 37 or 38 miles from Madras, a little east of Arconum junction, and the outcrop extends about 35 miles from north to south, being only interrupted for short distances by the alluvium of the Narnaveram and Naggery rivers, which divide it into three subequal divisions near Sattavedu, Alikúr, and Pyanúr respectively. The width of each of these areas is from 5 to 6 miles; in all of them the sandstones of the Gondwána series rest on the metamorphics (the underlying formation in one instance only consisting of Kadapa rocks) to the westward, and disappear to the east beneath laterite and alluvium; large outliers of the laterite being scattered over the sandstones of the Gondwána formations.

The northern portion of this tract, considering it as a whole, consists of the Sattavedu group, consisting chiefly of coarse compact conglomerate. This forms the whole of the Sattavedu area north of the Narnaveram river, and the greater portion of the central or Alikúr area. The southern portion of the latter, and the whole of the tract near Pyanúr, south of the Naggery river, consists of shales, sandstones, uncompacted conglomerate, and boulder beds belonging to the lower or Sripermatúr group. The boulder bed is always found at the base.

The next outcrop is that of Sripermatúr. It lies south-east of the last, being separated from the Pyanúr area by the alluvium of the Corteliar river and an expanse of laterite. The village of Sripermatúr at the northern extremity lies 25 miles west-south-west of Madras. From the neighbourhood of the village the Rájmahál beds are seen for about 15 miles to the southward, and their exposure extends about 9 miles from east to west at the northern end, but the breadth diminishes to the southward. The Rájmahál area is surrounded by laterite, but metamorphic rocks appear here and there through the superficial covering, whilst inliers of the Rájmahál beds are also found, shewing that they exist in places beneath the laterite. The base of the sandstones is nowhere seen.

The whole of this Sripermatúr tract is composed of the Sripermatúr group, and to the northward shales prevail, resting upon gritty sandstone, but in the southern portion of the area coarser beds are found. Remains of plants of Rájmahál species, together with a few higher forms, are common, and near Sripermatúr they are associated with marine shells, as already mentioned in the preliminary description of the group.

The outliers of these rocks to the south and south-west are numerous, but of small size. One group of nearly 30 small outliers, none of them exceeding 2 miles in length, whilst the majority are far smaller, is

scattered over the country south-west of Conjeveram. Another group of rather larger patches extends nearly in a line north and south, to the west of the main road from Madras to Trichinopoly, one outcrop, the southernmost and largest, which is about 4 miles long, being traversed by the road. All consist of Sripermatúr beds.

7. Trichinopoly or Utatur.—The outcrops of the Rájmahál group near Trichinopoly[1] occur in several isolated spots along the western edge of the cretaceous tract north of that town. They all rest upon metamorphic rocks to the westward, and dip to the east beneath the marine cretaceous beds, which rest upon them sometimes conformably, but generally with considerable unconformity, the plant beds having been extensively denuded before the deposition of the cretaceous rocks.

The series of Rájmahál outcrops comprises five distinct exposures, the most northern lying east of Perambalúr, whilst the southernmost is close to the village of Utatúr. The whole distance from north to south over which they are distributed is about 14 miles. The three southern outcrops are close together, and form a nearly continuous fringe to the cretaceous beds for between 6 and 7 miles.

The Rájmahál beds near Trichinopoly consist chiefly of soft sandy clays and micaceous shales, grey and brown in colour, with, at the base, coarse ferruginous sand, containing pebbles and large blocks of gneiss derived from the immediate neighbourhood. This bed is occasionally absent. The gneiss upon which these rocks rest is always greatly decomposed. Plant remains, principally *Ptilophyllum acutifolium*, occur here and there, but the impressions are rarely well preserved. The flora, like that of Sripermatúr and Ongole, appears to indicate a rather higher horizon than that of the typical Rájmahál beds.

[1] For account by Mr. H. F. Blanford, see Mem. G. S. I., IV, pp. 39–49.

CHAPTER XI.

PENINSULAR AREA.

MARINE JURASSIC ROCKS.

Distribution of marine jurassic rocks in India — Area occupied by jurassic beds in Cutch — Relations of Cutch jurassics to higher formations — Physical geology — Sub-divisions — Thickness — Pachham group (Bath) — Chari group (Kelloway and Oxford) — Katrol group (Upper Oxford and Kimmeridge) — Umia group (Tithonian and Portland) — Table shewing distribution of Cephalopoda — Jurassic beds in the great desert north of Cutch — Bálmir sandstones — Jesalmir limestones — Ammonite bed of Kuchri.

Distribution of marine jurassic rocks in India.[1]—In the last chapter the occurrence of marine formations belonging to the jurassic series, but associated with some of the higher Gondwána groups on the east coast of India, has already been noticed. It has been shewn that near Ellore and Ongole, and at Sripermatúr, near Madras, *Ammonites* and other *Mollusca*, with jurassic affinities, have been found in considerable numbers, but that, owing chiefly to the manner in which they are preserved, very few of the species have hitherto been determined, and

[1] The following jurassic fossils are figured on Plate XII :—

Fig. 1. *Belemnites gerardi.*
" 2. *B. grantianus v. kuntkotensis. B. grantianus v. Kuntkotensis.*
" 3. *Ammonites (Phylloceras) disputabilis.*
" 4. *A. (Aspidoceras) perarmatus.*
" 5. *A (Stephanoceras) macrocephalus.*
" 6. *A. (Perisphinctes) pottingeri.*
" 7. *Goniomya v-scripta.*
" 8. *Pholadomya granosa.*
" 9. *P. angulata.*
" 10. *Trigonia clavellata.*
" 11. *T. smeei.*
" 12 *T. costata.*
" 13. *Astarte major.*
" 14. *Arca (Macrodon) egertoniana.*
" 15. *Aucella leguminosa.*

The last two are Himalayan fossils. *Goniomya v-scripta* and *Trigonia clavellata* have not been found in India, but they are characteristically jurassic forms, and allied species

consequently the position of the beds in the jurassic series is, with one exception, still somewhat doubtful; the exception is near Ellore, where two different groups of marine beds have been distinguished, the higher of which corresponds to the Umia group of Cutch.

No other occurrence of jurassic rocks has hitherto been detected in the Peninsula of India itself, but to the north-west in Cutch, in what may be considered an intermediate belt of land between the Indian Peninsula and the remainder of Asia, in a country with the sea on one side and surrounded by alluvial deposits, connected indirectly with those of the great Indo-Gangetic plain, on all others, there is a very important series of jurassic formations, in which several European groups are admirably represented. Besides the area occupied in Cutch itself, the jurassic beds are found in places throughout a considerable area in the great desert to the northward, the best known outcrop being close to the town of Jesalmir.

Area occupied by jurassic rocks in Cutch.—The jurassic area of Cutch [1] may be considered as occupying a number of post-tertiary islands, now connected by alluvial flats. Of these islands the largest is that forming the western and central portion of Cutch, and is about 120 miles long from east to west and about 40 broad. To the north-east of it is the district of Wágad (Wagur or Wagir), another ancient island, nearly 50 miles from east to west, and, excluding alluvium and "Ran," 25 miles broad. Farther north, again, are four isolated masses of hills, chiefly composed of lower jurassic rocks, and extending in a line nearly 100 miles in length from east to west. These are the so-called islands in the Ran;[2] Pachham (Putchum), Kharir (Khurreer or Kurreer), Bela and Chorar; the first, which is farthest to the east, being the largest, and comprising a rock area measuring about 15 miles from east to west and 13 from north to south, whilst in Kharir the rock area measures 19 miles by 10, on Bela 22 by 6, and on Chorar 13 by 4; a few

[1] The rocks of Cutch were first described by Captain Grant, Geol. Trans., Ser. 2, V, p. 289.

The account of this province is taken partly from a report by Mr. Wynne, Mem. G. S. I., XI, pp. 1-293; partly from manuscript notes by the late Dr. Stoliczka. The *Cephalopoda* have been determined by Dr. Waagen, and described in the Palæontologia Indica, Ser. IX. It should, perhaps, be noticed that Dr. Waagen's views of specific distinction differ from those of many palæontologists, and that, as he points out, several of the forms described by him as species might by other naturalists not be considered to rank higher than varieties.

[2] The "Ran" of Cutch is an immense tract, surrounding the province on all sides, except the south, and consisting of barren salt marsh, periodically overflowed by sea water. This tract, which is evidently an ancient sea-basin, now filled up by alluvial deposits, will be further described in a subsequent chapter on post-tertiary and recent deposits.

smaller islands also occur, but none of them are of sufficient size to be worth notice.

Relations of Cutch jurassics to higher formations.—None of the rocks found in Cutch and the adjoining islands are of older date than jurassic. In one spot some limestones containing upper neocomian *Cephalopoda* are found resting upon the jurassic series, the uppermost group of which may perhaps itself be of intermediate age, and belong in part to a lower neocomian horizon.[1] In general the upper jurassic beds disappear to the south beneath the Deccan traps, but marine tertiary beds (nummulitic) overlap the traps and rest upon the older series in many parts of the country, both traps and nummulitic beds being quite unconformable to the jurassic formations.

Physical Geology.—The lowest beds are seen dipping to the south in the Ran islands, Pachham, Kharir, &c., and are again exposed in places in an anticlinal which runs along the northern edge of the province itself near the border of the Ran, the intervening synclinal being, for the most part, concealed beneath the Ran. From the anticlinal near the Ran there is a general dip, varying in amount, to the southward. The greater portion of the series is, however, repeated twice in consequence of a great fault, which runs from east to west along the northern scarp of the Chárwar range of hills south of Bhúj (Bhooj).

Sub-divisions.—By the earlier observers, including Mr. Wynne, the jurassic series in Cutch was simply divided into a lower and an upper group, the former chiefly marine, the latter apparently, for the most part, fresh water, though, as was shewn clearly by Mr. Wynne, no marked line of division can be drawn, for not only is there an absence either of unconformity or of any marked break in lithological character between the two sub-divisions, but marine beds are occasionally found interstratified with the upper, and plant beds with the lower group. The examination of the *Cephalopoda* by Dr. Waagen indicated the probability that representatives of several European jurassic groups existed in Cutch, and Dr. Stoliczka, re-examining the beds with the aid of Mr. Wynne's geological map and his own knowledge of palæontology, found no difficulty in distinguishing four sub-divisions, the three lower of which had been included in the inferior or marine group of previous observers, whilst the upper comprised the higher fresh-water beds, with the uppermost marine strata. The following are the names of the groups

[1] Dr. Stoliczka unfortunately did not live to publish the results of his examination of Cutch, but from his rough field notes it appears probable that the upper neocomian bed of Utra is conformable to the underlying Umia beds. He does not precisely state, however, what are the relations of the upper bed to the lower at this spot.

proposed by Dr. Stoliczka, with their homotaxial equivalents amongst European formations[1] :—

CUTCH.		EUROPE.	
GROUPS.	BEDS.	ZONES.	GROUPS.
	1. Beds with *Crioceras* and *Ammonites* of the *rotomagensis* group.		CRETACEOUS. *Upper Neocomian.*
	2. Sandstones and shales with *Cycadeæ* and other plants.	?	? WEALDEN.
UMIA .	3. Sandstones and conglomerates with marine fossils, *Ammonites* (*Perisphinctes*) *eudichotomus*, *frequens*, *Trigonia smeei*, *T. ventricosa*, &c.	Upper Tithonian . Lower Tithonian .	UPPER JURASSIC. *Tithonian and Portland.*
KATROL	4. Sandstones and shales with *Am.* (*Phylloceras*) *ptychoicus*, *A.* (*Oppelia*), *trachynotus*, *A.*(*Perisphinctes*) *torquatus*, *pottingeri*, &c.	Zone of *A.* (*Perisph.*) *mutabilis.* Zone of *A.* (*Oppelia*) *tenuilobatus.*	UPPER JURASSIC. *Kimmeridge.*
	5. Red ferruginous and yellow sandstones (Kantkot sandstones) with *Am.* (*Stephanoceras*) *maya*, *A.* (*Aspidoceras*) *perarmatus*, *A.* (*Perisphinctes*) *virguloides*, *leiocymon.*	? Zone of *A.* (*Pelt.*) *bimammatus.* ? Zone of *A.* (*Pelt.*) *transversarius.*	MIDDLE JURASSIC (middle oolite). *Oxford.*
	6. Oolites (Dhosa oolite) with *Am.* (*Stephanoceras*) *polyphemus*, *A.* (*Perisphinctes*) *indo-germanus*, *A.* (*Aspid.*) *perarmatus*, *babeanus*, *A.* (*Pelt.*) *arduennensis*, &c.	Zone of *A.* (*Amaltheus*) *cordatus.* Zone of *A.*(*Amaltheus*) *lamberti.*	
	7. White limestones with *Am.* (*Pelt.*) *athleta*, *A.* (*Oppelia*) *bicostatus*, &c.	Zone of *A.* (*Pelt.*) *athleta.*	MIDDLE JURASSIC (middle oolite). *Kelloway.*
CHARI .	8. Shales with ferruginous nodules with *Am.* (*Perisph.*) *obtusicosta*, *anceps*, *A.* (*Harpoceras*) *lunula punctatus*, &c.	Zone of *A.* (*Perisph.*) *anceps.*	
	9. Shales with calcareous bands and locally with golden oolite : *Am.* (*Steph.*) *macrocephalus*, *tumidus*, *bullatus*, *A.* (*Oppelia*) *subcostarius*, *A.* (*Perisph.*) *funatus*, &c.	Zone of *A.* (*Steph.*) *macrocephalus.*	
PACHHAM.	10. Light grey limestones and marls with *Am.* (*Oppelia*) *serriger*, Corals and *Brachiopoda*, &c.		MIDDLE JURASSIC (lower oolite). *Bath.*
	11. Yellow sandstones and limestones with *Trigoniæ*, *Corbulæ*, *Cucullææ*, &c.		

[1] Waagen; Pal. Ind., Ser. IX: Introduction.

Thickness.—The whole thickness of the Cutch jurassic series has been estimated by Mr. Wynne at 6,300 feet, of which 3,000, or very nearly half, belong to the uppermost group alone; the thickness of the other groups has not been estimated separately. It must be remembered that the base of the whole series is not exposed, and that the upper beds had suffered from denudation before they were covered by the traps.

Pachham group (Bath).—The Pachham group is thus named from its occurrence in the "island" of Pachham in the Ran. The lowest beds are exposed on the northern scarp of a range of hills, which runs east and west through all the Ran islands from Pachham to Chorar. The rocks composing the range dip south at a low angle; the crest of the hills and the surface of their southern slopes are formed of a thick massive bed of yellowish sandstone and limestone, containing *Corbula pectinata*, *Astarte compressa*, a *Trigonia* closely resembling *T. interlævigata*, *Cucullæa virgata* and other fossils.[1] Below the massive bed come shales and sandstones, all more or less calcareous, containing a *Rhynconella* near *R. concinna*, *Lima*, *Gervillia*, a small *Exogyra*, &c. The lowest bed seen in Pachham island is calcareous sandstone abounding in the small *Exogyra*. The same lower beds are seen in Koari Bet, a small islet north-west of Pachham, and on the northern flank of the range in Kharir, Bela, and Chorar, the top of the range in all cases consisting of the yellow calcareous rock. The thickness of this portion of the beds is at least 500 feet.

Besides forming the range of hills in the islands of the Ran, the Pachham limestone is exposed at four places in Cutch itself,—at Jarra, Kira hill near Chári, Jura hill, and in Halamán hill near Lodai, all situated along the northern edge of the main province of Cutch, near the borders of the Ran. In all these places the Bath rocks appear as inliers, exposed at the crest of an anticlinal, and surrounded on all sides by higher beds. At Jarra, about 50 miles north-west of Bhúj, there is a bed of white limestone containing *Scyphia*, a *Terebratula*, and small *Rhynconellæ*, and immediately above it a bed of corals. These rocks do not appear to be equally well exposed elsewhere; they are at the base of the Chári group, and are considered by Dr. Stoliczka as the uppermost beds of the Pachham group of Cutch.

The lower portion of the Pachham group has yielded no *Cephalopoda*, and the higher beds only eight species, all of which are rare. One is a *Nautilus*, *N. jumarensis*; the others are *Ammonites*, of which one belongs to

[1] As only the *Cephalopoda* of the Cutch beds have been properly compared, it is possible that some of the identifications of other fossils may require modification. Only those are mentioned which are in all probability correctly determined.

the sub-genus *Oppelia*, three to *Stephanoceras*, and three to *Perisphinctes*. One *Stephanoceras* is a variety of *Ammonites macrocephalus* (Pl. XII, figs. 3, 3*a*) the typical form of which is abundant in the next higher sub-division, and both the other species of *Stephanoceras* pass likewise into the lower beds of the Chári group. With the exception of *A. macrocephalus*, the only species found also in European rocks is *A.* (*Oppelia*) *serriger*, which was originally described from upper Bathonian beds. So far as the *Cephalopoda* are concerned, it would be difficult to correlate the Pachham group with any sub-division of the European oolites, but the Pachham *Brachiopoda*, which, however, have not been thoroughly compared, and the position of the beds immediately beneath the strata containing *A. macrocephalus* in abundance, have induced Drs. Stoliczka and Waagen to refer the group to the horizon of the Bath oolite (Bathonian).

Chari group (Kelloway and Oxford).—The next group in ascending order derives its name from the village of Chári, situated in Northern Cutch, about 32 miles north-west of Bhúj (Bhooj) and close to the borders of the Ran. This village has been known since the time of Captain Grant, the earliest geological explorer of Cutch, as an admirable locality for fossils, and especially for *Cephalopoda*, of which large numbers are found in the calcareous sandstones exposed around Kira hill.

The Chári group is composed of four sub-divisions, each marked by its mineral characters and by the fossils it contains. The group, as a whole, is in Cutch much more shaly than any of the other sub-divisions, but it contains hard bands of limestone or calcareous sandstone forming ridges, which are usually distinguished by characteristic forms of *Ammonites*.

The lowest of the four zones or sub-groups consists of shales, usually of a grey colour, with occasional bands of golden oolite, and sometimes nodular shaly limestone. The rock called golden oolite (which is not peculiar to India, but which is also found in the jurassics of Europe, and at about the same horizon) is very characteristic and easily recognised. It is a rather coarse-grained limestone, composed of calcareous grains, which are coated with a very thin ferruginous layer, and are surrounded by a matrix of carbonate of lime, so that the stone has much the appearance at first sight of a rock with golden-coloured mica. In places, as at Chári itself, the golden oolite is thick and conspicuous, but it is locally distributed and often wanting. The most characteristic fossils of these lowest Chári beds are *Ammonites* (*Stephanoceras*) *macrocephalus*, and allied forms of the sub-genus *Stephanoceras*.

Above the *macrocephalus* beds come dark shales, often black, with ferruginous bands and concretions. Sometimes, however, the nodules

are of white limestone, and the shales are locally sandy, and associated with sandstones, but the beds appear to preserve their lithological characters in general throughout Cutch. The chief palæontological peculiarity of this sub-division is the extreme abundance of a *Terebratula* considered by Sowerby a variety of the cretaceous *T. biplicata*. Planulate *Ammonites* (*Perisphinctes*) are also very common. The shales not unfrequently contain remains of plants, but no distinct impressions have been found.[1]

..nes only ' sub-division, in ascending order, is a very thin band, some-
'of limestone0 to 30 feet thick, of whitish or grey shale, with bands
brown. Usu..which are generally white, but occasionally yellowish or
its presence beneath 'and may be recognised easily by its colour and by
is *Ammonites* (*Peltocer* e Dhosa oolite. The most characteristic fossil
of this mollusk is usua) *athleta*, and in North-Western Cutch the shell

The uppermost Chári . anged into black calcspar.
tologically the most chara... vision is both lithologically and palæon-
though more developed than of...all. It is of no great ... it
reddish, or brown oolite, somet...

abounds in many places in a *Terebratula* closely allied to the cretaceous *T. sella*, and referred to that species as a variety by Sowerby: *Cephalopoda* are also extremely abundant.

The Chári beds are exposed in several places in Cutch, but they nowhere occupy a large area. They are found resting upon Pachham beds in the southern part of Pachham and Kharir islands, and in two small islands, Kakindiya and Gángta, south-east of Kharir (they form only the axis of a quaquaversal anticlinal on the latter); but none are exposed in Bela or Chorar, though a small area exists in the extreme north of Wágad. In these outcrops the sub-divisions are less well marked than to the southward, and the two characteristic *Terebratulæ* have not been noticed. In the mainland of Cutch, the Chári group occupies two series of inliers. One of these series is scattered at intervals along the northern anticlinal range; the rocks appear at three places west-north-west of Chári, again around Kira hill, near Chári, the typical locality; they extend nearly 12 miles from east to west around the Pachham beds of Jura hill, north of Bhúj, and they are found in two more outcrops farther east around Halamán hill, where they extend more than 6 miles,

[1] In Dr. Stoliczka's field notes he mentions having at one locality found fragments of quartz and of a limestone derived from one of the lower groups, probably from the Pachham beds, cemented together in the rock at this horizon. This may indicate unconformity.

and they again appear a mile farther east. Another series of outcrops occurs in the Chárwar range, south of Bhúj. Here the Chári beds are brought up at intervals along the southern side of the great fault; they are greatly disturbed and cut up by cross faults, but the different bands can be easily recognised,—the Dhosa Oolite with *Terebratula sella*, var., the white *athleta* beds, and the band with *T. biplicata*, var., being always conspicuous.

The relations between the *Cephalopoda* found in the different sub-divisions of the Chári group, and the corresponding Kelloway and lower Oxford groups in Europe, are the following, according to Dr. Waagen. The Chári fauna is very rich, comprising altogether 112 species, of which 37 are European. In the lowest Chári sub-division, or *macrocephalus* beds, 31 *Cephalopoda* have been found, *viz.*, 2 species of *Belemnites*, 3 of *Nautilus*, and 26 of *Ammonites*, of which 2, including *A. disputabilis* (Pl. XII, fig. 3), belong to the sub-genus *Phylloceras*, 1 to *Lytoceras*, 1 to *Oppelia*, 1 to *Harpoceras*, no less than 13, including *A. macrocephalus* (Pl. XII, figs. 5, 5*a*), to *Stephanoceras*, and 8 to *Perisphinctes*. Three are common to this sub-division and the upper Pachham beds, whilst none are known to range into higher strata. Sixteen species, or rather more than one-half, are found in Europe, all, except two, belonging exclusively to the beds with *A. macrocephalus* (Lower Kelloway).

In the next sub-division, the dark shales with *Terebratula biplicata*, var., 27 *Cephalopoda* are found, *viz.*, 3 *Belemnites*, 1 *Nautilus*, 1 *Ancyloceras*, and the remainder *Ammonites*, amongst which 2 belong to *Phylloceras*, 3 to *Oppelia*, 5 to *Harpoceras*, 1 to *Stephanoceras*, and 11 to *Perisphinctes*. Six of these range into higher beds, whilst 7 are European, and of these latter 5 are only found in the beds with *A. anceps* (Middle Kelloway).

The *Athleta* beds have yielded 20 species: 3 *Belemnites* and 17 *Ammonites* (*Phylloceras* 1, *Amaltheus* 2, *Oppelia* 2, *Harpoceras* 2, *Peltoceras* 1, *Aspidoceras* 2, and *Perisphinctes* 7); 5 of these are common to the next lower sub-division, and 2 to the Dhosa Oolite. Eight are European, six being peculiar to the zone of *A. athleta* (Upper Kelloway).

In the Dhosa Oolite no less than 34 *Cephalopoda* have been found, *viz.*, 4 *Belemnites*, 1 *Nautilus*, and 29 *Ammonites* (*Phylloceras* 2, *Harpoceras* 1, *Peltoceras* 5, *Aspidoceras* 4, *Stephanoceras* 8, and *Perisphinctes* 9); of these 4 range into higher and 3 into lower beds. Eight are found in Europe (the most important being *Am.* (*Aspidoceras*) *perarmatus* (Pl. XII, figs. 4, 4*a*); and of these seven belong exclusively to the zones of *A.* (*Amaltheus*) *lamberti* and *A.* (*Amalth.*) *cordatus* (Lower Oxford). This group also abounds in other fossils, especially, as already mentioned, in *Terebratula sella*, var.

Katrol group (Upper Oxford and Kimmeridge).—The Katrol group, which rests upon the uppermost sub-division of the Chári beds, is of considerable thickness. It consists of sandstones of various kinds, white, brown, pinkish-grey, &c., and shales usually grey or reddish, but sometimes very dark coloured like those of the *Am. anceps* zone. Ferruginous nodules and concretions sometimes occur in the shales which prevail towards the base of the group, the upper portion being chiefly sandstones. On the whole, however, shales predominate.

These beds form two belts in Cutch proper. The first occurs in the anticlinal along the Ran and extends for nearly 80 miles, surrounding the inliers of the Pachham and Chári groups, and extending to a considerable distance beyond them. The exposure of Katrol rocks varies in breadth, being, where broadest, nearly 10 miles wide. The second belt is in the Chárwar range, south of the great fault; this tract is about 35 miles from east to west, but nowhere more than 2 miles broad. Besides this, beds apparently belonging to the same group occupy the greater part of Wágad. The rocks are very similar in mineral character, consisting of coarse and fine grey, pinkish and white sandstones above, and grey or yellowish shales below; but the *Cephalopoda* found are almost all distinct, and appear to indicate a lower horizon. From their development around the town of Kantkot, these Wágad beds have received the name of Kantkot sandstone.

The *Cephalopoda* of this Kantkot sandstone are nineteen in number, 4 *Belemnites* and 15 *Ammonites* (*Phylloceras* 1, *Aspidoceras* 2, *Stephanoceras* 5, *Perisphinctes* 7). Four of these, *Am.* (*Aspidoceras*) *perarmatus*, *A.* (*Stephanoceras*) *maya*, *fissus*, and *opis*, are also found in the Dhosa Oolite of the Chári beds, whilst only one species, *Belemnites grantianus* (*B. kuntkotensis*, Pl. XII, fig. 2), is common to the Kantkot bed and the Katrol group in Cutch proper. Thus the Kantkot beds appear by their cephalopodous fauna allied more closely to the uppermost Chári beds than to the Kantkot group. Three species only of the Kantkot *Cephalopoda* are European, *A.* (*Asp.*) *perarmatus*, *A.* (*Per.*) *plicatilis*, and *A.* (*Per.*) *martelli*, and only one of these, the last, is limited to a single zone, that of *A.* (*Pelt.*) *transversarius* (Upper Oxford) in Europe, the other two ranging lower. Several forms are, however, allied to upper Oxfordian species.

The Katrol group proper has yielded 26 species of *Cephalopoda*, 4 *Belemnites* and 22 *Ammonites* (*Phylloceras* 2, *Lytoceras* 1, *Haploceras* 2, *Oppelia* 4, besides an *Aptychus*, *Harpoceras* 1, *Aspidoceras* 5, *Perisphinctes* 7). Only one of these species, *Bel. grantianus*, is found with certainty in any other group in Cutch. Four species are found in Europe, all belonging to the beds of the Kimmeridge group, with *A.* (*Asp.*) *acan-*

thicus. Of the above *Cephalopoda*, by far the most characteristic and abundant is a non-canaliculate Belemnite, *B. katrolensis*. The commonest *Ammonites* are *A.* (*Oppelia*) *kachhensis*, *A.* (*Per.*) *pottingeri* (Pl. XII, figs. 6, 6*a*), *A.* (*Per.*) *katrolensis*, and *A.* (*Per.*) *torquatus*.

Imperfect plant remains are common in the Katrol group, as they are in many of the lower beds of Cutch, but in one instance near the village of Narha, as has already been mentioned in the description of the Gondwána series, Mr. Wynne found, in shales interstratified with the Katrol beds, and distinctly inferior in position to some of the marine bands of the group, several remains of plants, of which four species, *Sphenopteris arguta*, *Alethopteris whitbyensis*, *Otozamites contiguus*, or an allied form, and *Araucarites cutchensis*, have been identified by Dr. Feistmantel. The relations of these plants have been already discussed on a previous page.

Umia group (Tithonian and Portland).—The Umia group derives its name from a small village in Western Cutch, rather more than 50 miles north-west of Bhúj. Taken as a whole, this group appears to equal in development all the other jurassic beds together, being, according to Mr. Wynne's estimate, upwards of 3,000 feet thick. It is the equivalent of the upper Jurassic group of Mr. Wynne's Memoir. As a rule, it consists of sandstones of various kinds, and more or less sandy shales. The sandstones are very often soft and white or pale-brownish, sometimes variegated, and very generally distinguished by thin bands of hard black or brown ferruginous grit. Occasionally the sandstones are variegated with pink, red, and brown; they are often very argillaceous and tend to decompose into a loose sandy soil, which covers and conceals the rocks over a great part of the country. In a few instances carbonaceous shale occurs, and in one locality, a thin seam of bright jetty coal. A few thin hard bands of sandstones are met with, some being so hard as to be almost a quartzite. There is a marked resemblance in the beds of this group to some of the upper Gondwána strata of Central India; there are the same soft argillaceous sandstones and sandy shales and the same hard ferruginous gritty bands.

Towards the base of the Umia group, there is a thick band of calcareous conglomerate, hard and grey, sometimes ferruginous, associated with sandstones and shales. In the conglomerate and in some associated beds marine fossils are numerous. Throughout all the rest of the group remains of plants are common, but they are not often sufficiently well preserved to be identified; marine fossils are very rare, but *Trigonia smeei*, the most typical fossil of the group, has been found in places, as near Vigor, 40 miles north-west of Bhúj, in beds near the top of the group and well above the horizon at which most of the plant fossils have been obtained.

The beds of the Umia group are covered unconformably by the Deccan traps and by tertiary rocks, except in one place, where, as already mentioned, they underlie the upper neocomian (Aptien) beds of Ukra hill in North-Western Cutch.

The surface occupied by the rocks of the Umia group corresponds in magnitude with the thickness of the formation, and embraces nearly, if not quite, half of the jurassic area in Cutch. In Cutch proper these beds extend throughout the province from the western extremity near Lakhpat to the eastern end beyond Bachao, forming a great plain south of the irregular range of hills along the edge of the Ran. They also extend round each end of the range, especially to the eastward, where the bottom Umia beds extend about 20 miles along the Ran north of the hills near Juran and Lodai. The main belt of Umia beds is from 8 to 12 miles across on an average; these rocks lap round the western end of the Chárwar range, where the great east and west fault, to which the range is due, appears to die out, and they cover another plain, nearly 50 miles in length from east to west and about 8 miles broad, south of the Chárwar range. They also form the western portion of Wágad.

The plant remains of the Umia group and their relations have already been described in the chapter relating to the Gondwána system. It was there shewn that 23 species had been identified, of which the commonest is *Ptilophyllum cutchense* (Pl. XI, figs. 3, 4), and of which 10 are either common to the lower oolitic beds of Yorkshire or represented by very closely allied forms. Bearing in mind that the plant beds are superior in position to all the portion of the group which has furnished *Cephalopoda*, it is remarkable to find that the latter exhibit a very decided upper oolitic (Portland and Tithonian) facies.

They are eleven in number,[1] *viz.*—

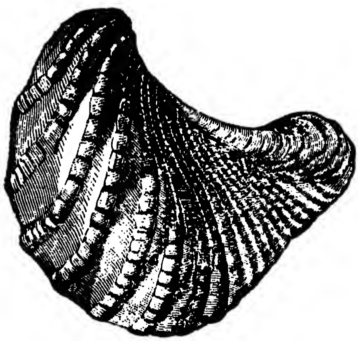
Belemnites grantianus (*kuntkotensis*).	*A.* (*Perisphinctes*) *bleicheri*.
Belemnites, 2 sp. indet.	*A.* (*Per.*) *occultefurcatus*.
Am. (*Haploceras*) cf. *tomephorus*.	*A.* (*Per.*) *eudichotomus*.
A (*Aspidoceras*) *wynnei*.	*A.* (*Per.*) *frequens*.
A. (*Perisphinctes*) cf. *suprajurensis*.	*A.* (*Per.*) *denseplicatus*.

Of these eleven species, one, *Belemnites grantianus* v. *kuntkotensis*, is found in lower beds in Cutch, and the two other forms of *Belemnites* are closely allied to the Katrol species *B. claviger* and *B. katrolensis*,

[1] Nine, according to Dr. Waagen, Pal. Ind. Ser. IX, pp. 225, 232, but he appears to have overlooked two forms—*Belemnites kuntkotensis* (*grantianus*), stated at page 4 to have been found in Umia beds, and the specimens from the same group doubtfully referred to *B. claviger*, p. 7. These very trifling and unimportant oversights are not noticed in order to call attention to a trivial error, but because the relations of the Umia group are of considerable importance and have been disputed. In consequence of the great importance of this group, the evidence upon which its relations to the upper jurassic beds of Europe are based is given in full.

and may be identical. All the eight *Ammonites* are restricted in Cutch to the Umia group, but two of them, *A. tomephorus* and *A. eudichotomus*, are Tithonian species found in the uppermost jurassic beds of Southern Europe, whilst *A. bleicheri* and *A. suprajurensis* are found in the Portland strata of Northern France, and *A. occultefurcatus* is barely distinguishable from another Portland species, *A.* (*Perisphinctes*) *boidini*, Lor. The connexion between the *Cephalopoda* of the Umia group and the forms found in the uppermost jurassic beds of Europe is consequently very marked, despite the small number of species found in the former, and Dr. Waagen states that the same marked similarity exists between the lamellibranchiate bivalves or *Pelecypoda* of the same beds in the two regions.[1]

The *Cephalopoda* are, however, rare and exceptional in the Umia group, and they form by no means so important a portion of the fauna as they do in the Chári, and even in the Katrol group. The commonest Umia fossils are two species of *Trigonia*, *T. smeei* (Pl. XII, fig. 11), and *T. ventricosa*, the latter being also found in the uppermost jurassic rocks of South Africa, whilst a very closely allied form, *T. tuberculifera*, occurs in cretaceous beds in Southern India. The occurrence of both of these *Trigoniæ* in jurassic beds associated with upper Gondwána strata on the east coast of India near Rájámahendri has already been noticed. Other forms of common occurrence in the Umia group are *Trigoniæ* allied to *T. vau*,



Trigonia ventricosa, natural size.

[1] Pal. Ind., IX, p. 225. Dr. Feistmantel, however (Rec. G. S. I., 1876, IX, p. 116), has contended that some of the forms found in the upper Cutch beds shew affinities to middle and lower jurassic forms. This is doubtless the case, and it is equally certain that some Umia fossils are allied to cretaceous forms, but no accurate conclusions as to the relations of a fauna can ever be attained by selecting a few species only for comparison. In the case of *Trigonia ventricosa* and a *Trigonia* related to *T. vau*, quoted by Dr. Feistmantel as proving an affinity to older formations, a mistake has been made in supposing that these fossils belong to beds in Africa of middle or lower jurassic age. This was formerly supposed to be the case (Q. J. G. S., 1867, pp. 169, 171, &c.), but it has since been shewn by Mr. Stow (Q. J. G. S., 1871, pp. 502, &c.) that *T. ventricosa* and *T. vau* are the characteristic fossils of one of the uppermost jurassic zones, resting upon a bed which contains *Hamites*, a cretaceous genus, and a neocomian form of *Crassatella*. The evidence, therefore, afforded by this important fossil, *Trigonia ventricosa*, confirms in a most signal manner the views adopted by Dr. Waagen from a study of the *Cephalopoda*. Some other Umia fossils appear also closely related to species found in the upper jurassics of Southern Africa; for instance, the *Gervillia* appears undistinguishable from the African *G. dentata*

T. clavellata (Pl. XII, fig. 10), and *T. gibbosa*, *Astarte major* (Pl. XII, fig. 13), a *Gervillia*, a peculiar *Gryphæa*, intermediate in form between *G. dilatata* and *G. vesicularis*, *Goniomya*, &c. Some of these range into lower groups also. A portion of the jaw of a *Plesiosaurus* was also obtained from these beds, and it has been described as *P. indicus*.[1]

Owing to the circumstance that, with the exception of the *Cephalopoda*, the large collections of fossils made in Cutch by Messrs. Wynne, Fedden, and Stoliczka have not hitherto been examined and compared, the distribution of many of the most characteristic species has not been definitely ascertained. Amongst the forms which are most abundantly preserved in the lower groups of the Cutch jurassic series are species of *Pleurotomaria*, *Pholadomya granosa* (Pl. XII, fig. 8), *Ph. angulata*, (Pl. XII, fig. 9), *P. inornata*, *Corbula lyrata*, *C. pectinata*, *Nucula cuneiformis*, *Cucullæa virgata*, *Trigonia costata* (Pl. XII, fig. 12), and *Ostrea marshii*.

Table shewing distribution of Cephalopoda.—The following table shews the general result of Dr. Waagen's examination of the Jurassic *Cephalopoda* found in Cutch:

Name of group.	Name of sub-division.	Total number of *Cephalopoda*.	Species peculiar to group.	Species ranging into higher beds.	Species ranging into lower beds.	Common to European jurassics.	Remarks.
Umia	3. Marine beds	11	9	—	2	4	Two of the European species occur in Portland beds of Northern France and two in Tithonian beds of Southern Europe.
Katrol	4. Katrol beds proper.	27	26	1	1	4	All the four European species belong to the zone of *Am. acanthicus* (Kimmeridge).
	5. Kantkot beds	19	14	1	4	3	
Chari	6. Dhosa Oolite (*Ter. sella* beds).	34	27	4	3	8	Seven characteristic of the zone of *A. transversarius* (Lower Oxford) of Europe.
	7. *Athleta* beds	20	13	2	5	8	Six characteristic of the zone of *A. athleta* in Europe.
	8. *Anceps* beds with *Ter. biplicata*.	27	21	6	—	7	Of the seven species found also in Europe, five are peculiar to the beds with *A. anceps*.
	9. *Macrocephalus* beds.	31	28	—	3	16	Fourteen out of the sixteen exclusively found in beds with *A. macrocephalus* in Europe.
Pachham	Upper	8	5	3	—	1 or 2	
	Lower	—	—	—	—	—	

The correspondence, not only with the European jurassic rocks as a whole, but with the different groups into which they are divided, is remarkable, and greater than is known in any other Indian formations, the

[1] Lydekker: Rec. G. S. I., IX, p. 154; X, p. 41.

only other series of Indian rocks of which the fauna has been sufficiently examined to justify the comparison—the cretaceous series of Southern India—shewing much less close agreement in the distribution of the fauna, and especially of the *Cephalopoda*, with the corresponding groups in Europe. The only remarkable instance in which the *Cephalopoda* of the Cutch jurassics differ from their representatives in the jurassic rocks of Europe, is in the prevalence in the Indian area of the *macrocephali* ammonites (*Stephanoceras*) at a higher horizon than in Europe. In Cutch they abound in the Dhosa Oolite and Kantkot sandstone, the other *Cephalopoda* of which are of Oxford, and in the latter case of upper Oxford types, whilst in Europe they are not known above the base of the Kelloway group. As will, however, be shewn in the next chapter, some of the cretaceous forms of *Ammonites* found in Southern India shew a remarkable resemblance to the jurassic forms of *macrocephali*, and in this instance they are associated with species allied to *Ammonites* characteristic of even older European deposits.

Jurassic beds in the great desert north of Cutch.—The occurrence of jurassic fossils in the wild semi-desert tract lying to the north of the Ran of Cutch has been known for many years. A few species were obtained from the country immediately north of the Ran by Sir H. Pottinger, and these were figured and described,[1] together with the much larger collections made by Captain Grant and Captain Smee in Cutch. Amongst the species thus obtained were *Ammonites pottingeri* and *A. torquatus*, both of which in Cutch have only been found in the Katrol group. The rocks immediately north of the Ran have never been explored by a geologist, but farther north, near Jesalmir, some jurassic *Ammonites* were discovered by Dr. Impey[2] in 1858, and a few data have since been added by a traverse made in 1876.[3] It is probable that a considerable area in the desert is occupied by jurassic strata, but the rocks are concealed throughout the greater portion of the region by a great thickness of sand. The only localities which have hitherto been examined are in the neighbourhood of Jesalmir to the north and Bálmir to the south.

Three beds in particular have been recognised amongst the strata exposed, but only one of these can be referred even approximately to a definite horizon amongst the Cutch series. The beds are in descending order:—

1. Ammonite bed of Kúchri.
2. Jesalmir limestones.
3. Bálmir sandstones.

[1] Geol. Trans., Ser. 2, V, p. 715, Pl. LXI.
[2] Jour. Bom. Br. R. A. S., VI, p. 161.
[3] Rec. G. S. I., X, pp. 10, 21.

Balmir sandstones.—The Bálmir rocks consist of sandstones, grits, and conglomerates, the most characteristic beds being whitish or greyish sandstone, very fine and compact, and a still finer rock approaching a compact-shale, white, but veined and blotched with purple. These beds must attain a considerable thickness, but only the lowest are well exposed, the upper strata being probably softer. The lower members of the group are well seen at Bálmir itself, where they rest upon the altered volcanic rocks of Maláni, and in some hills near Náosir, about 30 miles farther east. Fragmentary plant remains are common, but nothing sufficiently well preserved for determination has been found, and no remains of animals have been detected in the beds.

East and south-east of Jesalmir, beneath the marine jurassic beds of the next group, a considerable thickness of white, grey, and brown sandstones is exposed, interstratified with numerous bands of hard black and brown ferruginous sandstone and grit. Towards the base are some soft argillaceous sandstones, streaked and blotched with purple and closely resembling the Bálmir beds, except that they are less hard. These rocks probably belong also to the Bálmir group. They have a great resemblance to the Umia group of Cutch and to some of the Gondwána beds of the Central Provinces. The only fossils found, except fragments of leaves, are some pieces of dicotyledonous fossil wood.

Jesalmir limestones.—The sandstones and limestones of Jesalmir rest upon the beds last described, and consist of thick bands of compact buff and light brown limestone interstratified with grey, brown, and blackish sandstone, with some conglomerate. The limestone forms conspicuous scarps close to the town of Jesalmir, and it is highly fossiliferous, containing amongst other species *Terebratula biplicata, T. intermedia, Pholadomya granosa, Corbula lyrata, C. pectinata, Trigonia costata, Nucula cuneiformis, Pecten lens, and Nautilus kumagunensis. Ammonites* (*Stephanoceras*) *fissus* has been obtained from the neighbourhood, but very possibly from a different horizon, for in Cutch it belongs to the Dhosa Oolite and the Kantkot sandstone (both Oxford), whilst *Nautilus kumagunensis* is only found at a lower horizon in the beds with *Am. macrocephalus* at the base of the Chári group. *Terebratula biplicata* in Cutch is chiefly characteristic of a rather higher horizon than that of the *macrocephalus* beds. There can, however, be but little hesitation in referring the Jesalmir limestones to the age of the Chári group.

Ammonite bed of Kuchri.—The Ammonite bed of Kúchri is exposed about 25 miles west-north-west of Jesalmir, and consists of a thin bed of buff and brownish limestone, weathering red where exposed, and abounding in yellow *Ammonites* of three or four species. None of the *Ammonites* can be safely identified with any Cutch species, though one

form is very near *A.* (*Stephanoceras*) *opis*, which, like *A. fissus*, is common to the Dhosa Oolite and Kantkot sandstone. Below the Ammonite beds are dark calcareous sandstones resting upon soft white sandstone, and similar beds are found above, the whole being capped, a few miles to the westward, by nummulitic limestone. The relations between the Kúchri bed and the Jesalmir limestone are not clearly seen, but the former appears to be higher in the series.

Jurassic rocks, probably belonging to the Umia group, have recently been found by Mr. Fedden to exist in Northern Kattywar. To the north of Jesalmir the rocks may extend into Bikanir. The jurassic rocks of the Panjáb Salt Range and of the Himalayas will be described in a subsequent chapter.[1]

[1] After the first pages of this chapter had been passed for press, it was noticed that an omission of some importance had been made with regard to the Ammonites of the Sripermatúr beds; *ante*, pp. 149, 250. Dr. Waagen, Pal. Ind., Ser. IX, p. 236, pointed out that these *Cephalopoda* resembled Neocomian rather than Jurassic types. As, however, owing to the poor state of preservation, the species cannot be determined, Dr. Waagen has himself noticed (Denkschrift mat. nat. klasse K. Akad. Wiss. Wien., 1878) that too much weight must not be attached to so imperfect an identification.

CHAPTER XII.

PENINSULAR AREA.

MARINE CRETACEOUS ROCKS.

Neocomian beds of Cutch — Middle and upper cretaceous beds of India — Cretaceous rocks of Trichinopoly and Pondicherry — Area occupied — Sub-divisions — Utatúr group — Distribution — Palæontology — Trichinopoly group — Distribution — Palæontology — Arialúr group — Distribution and relations to lower groups — Palæontology — Uppermost Arialúr beds of Ninnyúr — Relations between faunas of different groups — Physical geography of Southern India in cretaceous times — Connexion with cretaceous rocks in other parts of India — Relation to cretaceous rocks of South Africa — Cretaceous fossils of Sripermatúr near Madras — Cretaceous beds of the Narbada valley or Bágh beds — Mineral characters and distribution — Physical geology — Palæontology — Relations to cretaceous fauna of Southern Arabia.

Neocomian beds of Cutch.—Before proceeding to describe the other cretaceous rocks[1] of the Indian Peninsula, all of which are of middle or upper cretaceous age, it may be useful to notice briefly the existence of a band belonging to a lower cretaceous horizon in Cutch.[2] To the occurrence of this band attention has already been directed in the description of the jurassic beds of the same province.

[1] The following cretaceous fossils are figured on Plate XIII:—

Fig. 1. *Ammonites rotomagensis.*
" 2. *A. planulatus.*
" 3. *Turrilites costatus.*
" 4. *Baculites vagina.*
" 5. *Aporrhais securifera.*
" 6. *Avellana scrobiculata.*
" 7. *Cardium (Protocardium) hillanum.*
" 8. *Trigonia scabra.*
" 9. *Inoceramus simplex.*
" 10. *Pecten (Vola) quinquecostatus.*
" 11. *Hippurites organisans.*
" 12. *H. cornuvaccinum* (transverse section).

All are Indian fossils, except the *Hippurites*, which have been introduced because of the great abundance of forms belonging to the genus in many cretaceous formations found in parts of Europe and Asia.

[2] The only published account of this bed is in the "Palæontologia Indica," Ser. IX, Jurassic Cephalopoda of Cutch, pp. 245-247. No account of the locality was ever printed by the discoverer, Dr. Stoliczka, and his note-books contain scarcely any details on this particular point.

The only representative of the marine cretaceous formations known to occur in Cutch is a thin bed of ferruginous oolitic rock which occurs at the base of the Deccan traps forming Ukra hill, 7 miles south-east of Lakhpat, in North-Western Cutch, and rests upon beds of the Umia group. The outcrop is very ill seen, and nothing has been definitely ascertained as to the degree of conformity between the cretaceous bed and the underlying formation, but there appears to be no marked contrast between them.

The following three fossil *Cephalopoda* have been obtained from this locality :—

Ammonites martini.
A. deshayesi.
Crioceras australe.

Of these the two former occur in the lower greensand (neocomian) of Europe, and are most characteristic of the upper portion (Aptian of D'Orbigny); the third has been found in cretaceous beds of Australia, the exact horizon of which is not known.

Middle and upper cretaceous beds of India.—Excluding Cutch, there are but two areas, widely separated from each other, in which marine cretaceous rocks have hitherto been described as occurring in the Indian Peninsula. The most important of these is in the neighbourhood of Pondicherry and Trichinopoly in Southern India; the other is in the Narbada valley between Mandlesir and Broach. Fragments of sandstone containing cretaceous fossils have been found at Sripermatúr near Madras, but the rock has not been discovered in place. There is a third locality for marine fossils, which should, in all probability, be classed as cretaceous, in the neighbourhood of Ellore, but as the deposits are associated with outbursts of the Deccan trap, it will be best to treat of them in connexion with the rocks of that series. Cretaceous rocks are also found in Sind, the Panjáb Salt Range, and Spiti, north-east of the peninsular area; whilst to the north-east and east, beds of the same age occupy a considerable, but little known, area in Assam and Burma.

As the cretaceous rocks of Southern India have been carefully examined, and the magnificent series of fossils procured from them exhaustively described, they will first be noticed.

Cretaceous rocks of Trichinopoly and Pondicherry.—The occurrence of cretaceous rocks in Southern India was first observed in 1840 by Mr. Kaye of the Madras Civil Service, who, in company with Mr. Brooke Cunliffe and others, collected a large series of fossils, which were examined by Professor E. Forbes. The rocks near Pondicherry had, however, some years before attracted the notice of Mons. E. Chevalier, but no account of them was published until after the appearance of

Mr. Kaye's description. A collection of fossils from the neighbourhood of Pondicherry was examined by Mons. A. D'Orbigny, and referred to an upper cretaceous age. Professor E. Forbes, on the other hand, referred the beds of Trichinopoly and Verdachellam to the age of the upper greensand or gault, and the Pondicherry beds to the neocomian. It was shewn by Mr. H. F. Blanford that beds of two ages exist near Pondicherry, and he, following Professor Forbes, considered the lower of these or Valudayur beds neocomian and older than any of the Trichinopoly rocks, but the thorough examination of all the Southern Indian fossils by Dr. Stoliczka has proved that the general homotaxis is middle and upper cretaceous, and that the neocomian and oolitic forms, which led to a portion of the beds being originally classed as lower cretaceous, are less numerous than the middle cretaceous species with which they are associated. It was also found that the fauna of the Valudayur beds had more species than was at first supposed in common with the lowest group of the Trichinopoly area, and the two were consequently considered identical. The *Cephalopoda* of the lower beds comprise several species found in the gault of Europe, and the number was at first supposed to be larger than it proved on subsequent closer investigation; but as there are scarcely any representatives of gault forms amongst the very numerous and beautifully preserved *Gasteropoda* and *Lamellibranchiata* (*Pelecypoda*), the whole of the Southern Indian beds were finally referred by Dr. Stoliczka to an age not older than the upper greensand of England (cenomanian), and ranging thence to the upper chalk (senonian).

The rocks of cretaceous age in Southern India [1] occupy, with relation to older and newer formations, a very similar position to that of the outcrops of upper Gondwána beds farther to the northward. The cretaceous beds occur in the great plain which extends along the Coromandel Coast, from the north of the Godávari to Cape Comorin. They rest to the west upon the gneiss or occasionally upon small patches of the upper Gondwána (Rájmáhal) beds themselves; they have a low dip to the eastward, and are covered up on the east by tertiary beds, known as Cuddalore sandstones, and by the alluvium of the sea-coast. The cretaceous beds are exposed at the surface in three detached areas, separated from each other by the alluvial deposits of the Puniar and Vellaur rivers; of these areas the southern and largest, between the Vellaur and Coleroon rivers, is in the Trichinopoly district, and known as the Trichinopoly area. North

[1] For a complete description of the geology by Mr. H. F. Blanford, see Mem. G. S. I., Vol. IV, pp. 1–217. The fossils are described and figured in four volumes, comprising Series I, III, V, VI, and VIII of the "Palæontologia Indica," all by Dr. F. Stoliczka, with the exception of the *Belemnites* and *Nautili*, which are by Mr. H. F. Blanford. Some additional notes on the *Cephalopoda* are published in the Rec. G. S. I., Vol I, p. 32.

of Vellaur are two much smaller exposures near Verdachellam and Pondicherry respectively, and named from those towns.

Area occupied.—The Trichinopoly area extends about 25 miles from north to south, and is of about the same breadth where widest, but it is very irregular in form. South of the Coleroon (the principal outlet of the river Cauvery) no cretaceous beds have hitherto been clearly traced, though representatives may perhaps occur south of Trichinopoly and east of Madura, but the southern boundary of the cretaceous area, north of the Coleroon, is chiefly formed by gneiss, and metamorphic rocks appear again to the south of the alluvial flat through which the river runs. To the northward, however, the cretaceous rocks disappear beneath the alluvium of the Vellaur river and re-appear north of the river at Verdachellam (Vriddachellam), forming the Verdachellam area, in which, however, only the highest cretaceous group is exposed, and even this is only visible at very few points. It occupies a tract of country about 15 miles long from north-north-east to south-south-west, by about 5 broad, with gneiss to the west and tertiary Cuddalore sandstone to the east. There is a second break in the rocks at the Panár river, and alluvium extends to the neighbourhood of Pondicherry, causing an interval of about 25 miles in the belt of cretaceous rocks before they reappear near Valudayur, 10 miles west by north from Pondicherry. Here they occupy a small tract of country about 12 miles long from north-east to south-west, by 6 miles broad, and only separated from the sea on the east by a band of Cuddalore sandstones 2 to 4 miles wide. To the west is a narrower strip of Cuddalore sandstone, beyond which the country consists of gneiss.

Sub-divisions.—In all three areas there appears to be a low dip to the east, the lowest beds appearing at the western boundary and higher groups succeeding in regular order to the eastward. Many of the dips seen in the rocks are, however, deceptive, being due to oblique lamination or false bedding, which prevails extensively throughout the series, and especially in the southern portion of the Trichinopoly area. In the Verdachellam and Pondicherry areas the rocks are ill seen, and the dips are less distinct, but there appears every probability that the same low dip prevails in the Pondicherry or Valudayur area; the direction is, however, south-east rather than east.

The cretaceous series in Southern India is divided into three groups, named in descending order Arialúr, Trichinopoly, and Utatúr. The following table taken from the "Palæontologia Indica[1]" exhibits Dr. Stoliczka's

[1] Ser. VIII, Introduction, p. ii. In the original there are several slight errors or misprints in the fossil names, and it is probable that the proof was not corrected by Dr. Stoliczka.

final views as to the representation by these groups of the European cretaceous sub-divisions:

	South India.	England.	France.	Germany.
Arialur group.	Zone of *Nautilus danicus* and *Ammonites ootacodensis*, *Ostrea pectinata*, and *O. ungulata*, *Gryphæa vesicularis*, *Inoceramus cripsii*, *Crania ignabergensis*.	Upper chalk	Senonian ...	Ober Quader.
Trichinopoly group.	Zone of *Ammonites peramplus*, *Pholadomya caudata*, *Modiola typica*, *Ostrea diluviana*, *Rhynconella compressa*.	Lower chalk	Turonian ...	Mittel Quader.
Utatur group.	Zone of *Ammonites rostratus* and *rotomagensis*, *Inoceramus labiatus*, *Exogyra suborbiculata* (*Gryphæa columba*), and *Terebratula depressa*.	Chalk marl and upper greensand.	Cenomanian or Tourtia.	Unter Quader, Unterer Quadersandstein, and Unterer Pläner.

Utatur group.—The Utatúr group derives its name from a large village 20 miles north-north-east of Trichinopoly. The beds composing the group are chiefly argillaceous; fine silts, calcareous shales, and sandy clays, frequently concretionary, and more or less tinted with ochraceous matter, prevail throughout the group, and in the southern portion of the area constitute almost the entire bulk of the deposit. North of the villages of Garudamangalam and Kauray, both in the neighbourhood of Utatúr, limestone bands become intercalated in the lower or western part of the group, and sands, grits, and conglomerates in the upper or eastern part, these changes in mineral character being accompanied by a great enrichment of the fauna in the first case and an impoverishment in the other. Conglomerates are of very rare occurrence in the lower beds. Gypsum occurs in most of the argillaceous strata, and is to a certain extent characteristic of the sub-division. The dips are often irregular, and apparently due to the original deposition of the beds on shelving banks. This irregularity of dip renders it impossible to form any trustworthy estimate of the thickness attained by the group as a whole; it may, however, be roughly estimated as probably not less than 1,000 feet.

At the base of the Utatúr group, there are, in several places, large masses of coral reef limestone, resting sometimes on the plant beds (upper Gondwána), but more frequently on the gneiss, and occasionally on the

lowest beds of the Utatúr group itself. The rock is a nearly pure pale-coloured limestone, compact and homogeneous, but often with a flaggy structure, and frequently irregularly banded with white streaks, which, on weathered surfaces, exhibit the corals of which they are composed. The mass of the rock also sometimes abounds in corals, but more frequently no organic structure can be traced. In lithological character this rock precisely resembles the coral reef limestone of the present day, as described by Darwin, Dana, Jukes, and other observers.

The usual position of this limestone is at the base of the Utatúr group, resting upon older rocks. The coral reefs appear to have been frequently exposed to denudation during the deposition of the later Utatúr beds, amongst which, in places, calcareous bands are found, apparently derived from the waste of the reefs. The coral limestone now remains in the form of small isolated patches, scattered along the western and southern margins of the cretaceous beds. In one locality, however, close to the village of Cullygoody, on the southern boundary of the cretaceous area, and 20 miles north-east of Trichinopoly, by far the largest outcrop of the limestone in the area occurs at the base of the Trichinopoly group. This outcrop is of considerable breadth, and extends, with one or two breaks, for about 6 miles. From an examination of all the circumstances, however, it has been satisfactorily ascertained that this outcrop also belongs to the Utatúr group, and that the Trichinopoly group rests unconformably upon it.

The coral reefs appear to have been scattered over the sea bottom in shallow water, and probably along the coast, at the commencement of the period during which the cretaceous deposits of Southern India were formed. The remaining beds of the Utatúr group were probably deposited in water of moderate depth, and some of them appear to have accumulated on submarine banks formed possibly by tidal channels. Hence the false bedding so prevalent in the rocks. The coarser constituents of the rocks to the northward appear to indicate that the current which brought the sediment flowed from that direction, and the occurrence of littoral forms of mollusca in greater abundance throughout the northern parts of the area may be accounted for in the same manner. The beds in the southern portion of the Utatúr area appear to have been formed of fine silt deposited in a bay where the force of the current was less than to the northward, and the fossils which occur are mostly the remains of pelagic animals, such as *Belemnites*, or a few *Ammonites*, chiefly of the *Cristati* group, or else peculiar forms of *Vermetidæ* (*Tubulostium discoideum* and *T. callosum*), which probably lived in the mud. The *Ammonites* and *Nautili*, which are numerous to the northward, are scarce in the southern portion of the area. Cycadeaceous (exogenous)

fossil wood, sometimes bored by *Teredo* and other *Pholadidæ*, abounds in certain parts of the group. On the whole, there appears every reason to believe that the Utatúr beds were formed in the neighbourhood of a coast line.

Distribution.—The distribution of the Utatúr beds in the Trichinopoly district is very simple. They form the western portion of the cretaceous area throughout: their outcrop being in general from 3 to 5 miles broad, except to the northward, where it diminishes in consequence of the beds being overlapped by those of the next group, till, in the northern portion of the tract at the village of Olapaudy, the breadth of the Utatúr outcrop does not exceed half a mile. At the extreme northern point of the area, both the Utatúr and Trichinopoly groups are completely overlapped by the uppermost subdivision.

The Utatúr beds are not represented in the Verdachellam area, but they reappear, as already mentioned, near Pondicherry. Here the beds formerly classed as the Valudayur group, and considered neocomian by Forbes, but which were shewn by Stoliczka to contain several species of fossils common to the Utatúr group, consist chiefly, like the strata near Utatúr, of argillaceous beds, sandy shales and sands, with occasional bands of limestone and calcareous concretionary nodules. Amongst the lowest beds seen conglomerates occasionally occur; but the most characteristic band is composed of dark-grey compact limestone in large nodules, sometimes highly fossiliferous; *Baculites vagina* (Pl. XIII, fig. 4) being the commonest fossil.

The area occupied by the Utatúr or Valudayur beds near Pondicherry extends from Valudayur for about 9 miles to the north-east and is about 4 miles broad. The beds are not seen to rest upon any older formation; north and south the country is covered with alluvium; to the eastward the Utatúr beds disappear beneath the Arialúr group, and to the westward beneath the Cuddalore sandstones of Trivicary. The beds to the westward appear to be the lowest, and there is a dip to the eastward.

Palæontology.—The fauna of the Utatúr group is very rich, no less than 297 species of *Invertebrata* having been described from it. It has yielded an especially large number of *Cephalopoda*, 109 species, of which 95 have not been met with in the Trichinopoly or Arialúr group. Of these 109 species 27 are known to occur in Europe or elsewhere out of India, and although the majority are distinctly and characteristically middle cretaceous forms, 3 are, in Europe, neocomian species, *viz.*, *Nautilus neocomiensis*, *Ammonites velledæ*, and *A. rouyanus*, whilst no less than 9 are found in the gault, several of the latter

ranging, however, into the upper greensand (cenomanian). Amongst the forms which are not European, the most remarkable are 3 species belonging to the section of *Ammonites* known as *Globosi*, which, amongst European rocks, are especially characteristic of the triassic period. A very large proportion of the *Cephalopoda* were collected in the neighbourhood of two villages, Odium and Maravattúr, on the road from Perambalúr to Arialúr, and about 12 miles north-east of Utatúr.

The *Gasteropoda* comprise, on the other hand, only 43 species, a number far inferior to that found in each of the other groups; the majority are littoral forms. The *Lamellibranchiata* (*Pelecypoda*) are 79 in number; the *Brachiopoda* 9, *Echinodermata* 10, and corals 42, with one species of sponge and one annelid. The forms found also in other countries belong almost without exception to the upper greensand (cenomanian) or higher groups, thus presenting a remarkable difference from the *Cephalopoda*, in which gault forms are so largely represented. The only fossils, besides the *Mollusca*, which are of much importance, are the corals, which, from the prevalence of reefs at the base of the group, are superbly represented, no less than 42 species being known to occur, belonging to 23 genera, *viz.*, *Caryophyllia*, *Platycyathus*, *Trochosmilia*, *Lophosmilia*, *Epismilia*, *Psammosmilia*, *Stylina*, *Thecosmilia*, *Holocœnia*, *Astrocœnia*, *Mycetophyllia*, *Stelloria*, *Heliastræa*, *Placastræa*, *Isastræa*, *Latimæandra*, *Thamnastræa*, *Dimorphastræa*, *Comoseris*, *Thecoseris*, *Eupsammia*, *Coscinaræa*, and *Heliopora*.

The following is a list of all the most common and important species of *Invertebrata* found in the Utatúr group, those forms which are especially abundant and characteristic being marked by an asterisk, thus*. Some species of comparatively rare occurrence in India are included, because they are well-known European forms, and therefore of importance to shew the relations of the group. Some others are remarkable, as shewing the presence of genera not found elsewhere in cretaceous rocks. All kinds found also in Europe or in other continents besides Asia are marked *e*, and the name of the formation or formations in which they are found is appended.

[1] All the details of the cretaceous fauna are from the four volumes of the "Palæontologia Indica" by Dr. Stoliczka. It was the author's intention after completing the work to have gone over the cretaceous country in Southern India, which he had never visited; and had he lived to examine the beds, much that is now obscure would doubtless have been cleared up, and the position of all the fossils accurately determined. So far as has been possible, all fossils of doubtful origin are omitted in the lists given. Amongst such large collections as those from Southern India, it is almost impossible to avoid some errors of locality if the collector is not the describer.

CEPHALOPODA.

BELEMNITIDÆ—
- * *Belemnites fibula.*
- e * *B. semicanaliculatus*, aptian to lower chalk.
- *B. seclusus.*

NAUTILIDÆ—
- e *Nautilus neocomiensis*, neocomian.
- *N. huxleyanus.*
- *N. ootatoorensis.*
- e * *N. pseudo-elegans*, neocomian.

AMMONITIDÆ—
- e * *Ammonites rostratus* (*A. inflatus*, Sow.), middle cretaceous.
- *A. siva.*
- e * *A. rotomagensis*, Pl. XIII, fig. 1, middle cretaceous.
- e *A. navicularis*, cenomanian; lower chalk.
- e * *A. mantelli*, gault; cenomanian.
- *A. vicinalis.*
- e *A. dispar*, cenomanian.
- *A. garuda* (*A. indra*).
- e *A. subalpinus*, gault.
- e *A. velledæ*, neocomian; middle cretaceous.
- e *A. rouyanus*, neocomian.
- *A. diphylloides.*
- *A. rudra.*
- *A. xetra.*
- *A. telinga.*
- *A. yama.*
- *A. durga.*
- e * *A. timothianus*, gault; grés vert.
- e *A. latidorsatus*, aptian; gault; grés vert.
- *A. madraspatanus.*
- *A. cala.*
- *A. sacya.*
- *A. kayei.*
- *A. papillatus.*
- *Scaphites similaris*, Stol. (*S. æqualis*, Sow. *apud* Stoliczka, *olim.*).
- e *S. obliquus*, middle cretaceous.
- e *Anisoceras armatum*, middle cretaceous.
- *A. rugatum.*
- *A. indicum.*
- e *Turrilites bergeri*, gault.
- e *T. gressleyi*, gault.
- e *T. tuberculatus*, gault.
- e *T. costatus*, Pl. XIII, fig. 3, gault to lower chalk.
- *Hamites problematicus.*
- *Hamulina sublævis.*
- e *Ptychoceras gaultinum*, gault.
- * *Baculites vagina*, Pl. XIII, fig. 4.
- e *B. gaudini*, gault.

GASTEROPODA.

ALATA—
- e *Alaria parkinsoni*, gault; cenomanian.

VOLUTIDÆ—
- *Ficulopsis pondicherriensis.*

PYRAMIDELLIDÆ—
- e *Nerinæa incavata*, turonian.

TURRITELLIDÆ—
- e *Turritella nerinæa*, senonian.
- e *T. nodosa*, cenomanian.

VERMETIDÆ—
- * *Tubulostium discoideum.*
- * *T. callosum.*

LITTORINIDÆ—
- *Littorina attenuata.*

NATICIDÆ—
- * *Tylostoma ootatoorense.*
- *Euspira spissata.*

TROCHIDÆ—
- *Delphinula annularis.*

PLEUROTOMARIIDÆ—
- *Pleurotomaria glabella.*
- *Leptomaria indica.*

ACTÆONIDÆ—
- *Actæonina columnaris.*
- *Trocactæon cylindraceus.*
- e *Avellana elongata*, cenomanian.

DENTALIIDÆ—
- *Antale glabratum.*

LAMELLIBRANCHIATA.

PHOLADIDÆ—
- *Teredo partita*, and two other species.
- *Martesia tundens*.
- *Parapholas mersa*.

GASTROCHÆNIDÆ—
- *Rocellaria guttula*.

MYIDÆ—
- *Corbula minima*.

ANATINIDÆ—
- *Corimya pertusa*.

SAXICAVIDÆ—
- *Saxicava tenella*.

CARDIIDÆ—
- *Protocardium altum*.
- *Fragum praecurrens*.

LUCINIDÆ—
- *Lucina fallax*.

NUCULANIDÆ—
- *Nuculana socialis*.

ARCIDÆ—
- *Trigonoarca gamana*.

AVICULIDÆ—
- *Aucella parva*.
- *Inoceramus geinitzianus*.
- e *I. labiatus*, middle cretaceous.

RADULIDÆ—
- *Radula* (*Limatula*) *persimilis*.

PECTINIDÆ—
- *Pecten verdachellensis*.
- *P.* (*Syncyclonema*) *obovatus*.
- e *Vola lævis*, cenomanian.

SPONDYLIDÆ—
- *Plicatula sessilis*.
- *Spondylus subcostulatus*.

OSTRÆIDÆ—
- e *Exogyra haliotoidea*, middle cretaceous.
- e *E. costata*, upper cretaceous.
- e *E. suborbiculata* (*Gryphæa columba*, auct.), middle cretaceous.
- e *E. canaliculata*, middle cretaceous.
- e *Gryphæa vesiculosa*, ditto.
- e *Ostrea* (*Alectryonia*) *diluviana*, ditto.
- e *O.* (*A.*) *carinata*, ditto.

BRACHIOPODA.

- e *Terebratula depressa*, cenomanian (? and neocomian).
- e *Terebratula obesa*, cenomanian; turonian.

ECHINODERMATA.

- *Hemiaster inæqualis*.
- *Cassidulus emys*.
- *Cassidulus planatus*.
- e *Cidaris hirudo*, cenomanian.

ANTHOZOA.

- e *Trochosmilia tuba*, turonian.
- *Stylina multistella*.
- *Holocænia ramosa*.
- * *Astrocænia retifera*.
- *A. reussiana*.
- *Isastræa expansa*.
- *I. siva*.
- *I. cyathina*.
- *Thamnastrea hieroglyphica*.
- *Eupsammia varians*.

SPONGIOZOA.

- e *Siphonia pyriformis*, cenomanian.

Trichinopoly group.—The Trichinopoly or middle group of the Southern Indian cretaceous series derives its name from the district of Trichinopoly, to which it is, so far as present exploration extends, entirely restricted. To the south it consists chiefly of sands and clays,

very irregularly bedded, with a few bands of limestone and some conglomerates, and it differs lithologically only in one important respect, which will be described presently, from the Utatúr group. North of the neighbourhood of Alandanapuram and Garúdamangalam. east of Utatúr, regular bands of shell-limestones become intercalated in the lower beds of the deposit, and to the northward the whole group is composed of regularly stratified alternations of sand, sandy clays, and shales, with bands of shell-limestone, calcareous grit and conglomerate.

The peculiarity just mentioned by which both the Arialúr and Trichinopoly beds in the southern part of the cretaceous area are distinguished from the Utatúr consists in the occurrence of granite pebbles in considerable quantity in the gravels and conglomerates of the two former, whilst none are found in the lower sub-division. In the Utatúr group the materials of the few conglomeratic or gravelly beds which occur are derived either from the gneiss or from the coral reef limestone, whilst in the two upper groups conglomerates are more frequently met with, and loose masses of unstratified gravel and beds of rolled pebbles, almost entirely composed of granitic materials, and resembling the shingle of a sea-beach, are of common occurrence. The source of the granite pebbles was evidently the broad belt of granitic rocks which forms the southern boundary of the cretaceous area, and divides it from the alluvium of the Cauvery throughout the greater portion of its extent; and the necessary inference is, that this band of rock was in all probability beneath the sea during the deposition of the Utatúr beds, and that it was elevated above the water in the interval between the Utatúr and Trichinopoly periods.

The Trichinopoly beds are, even more characteristically than the Utatúrs, the littoral deposits of a shallow sea. This is proved, not only by the frequent occurrence of coarse sediment and the great irregularity of the deposits in part of the area, but by the abundance of fossil wood, almost exclusively exogenous, and apparently Cycadeaceous. Trunks of trees are met with of great size, as much as 3 feet in diameter and 60 feet in length; much of the wood being perforated by boring mollusca.

The shell-limestone of Garúdamangalam and other places is a very fine hard bluish-grey translucent rock, usually abounding in beautifully preserved shells, both *Gasteropoda* and *Lamellibranchiata*, which retain their original polish, and occasionally even the coloration of their surfaces. This rock is largely quarried for ornamental purposes, and is known as "Trichinopoly marble:" it has yielded a considerable proportion of the fossils found in the group. The limestone occasionally contains pebbles of granite or fragments of fossil wood, either of which is sufficient to distinguish it, even when it is unfossiliferous, from the Utatúr limestones.

The beds of the Trichinopoly group are unconformable to the Utatúrs, upon which they rest throughout the greater part of the area, the evidence of unconformity not being confined to overlap, but depending chiefly upon the proof, afforded by the rocks at the southern edge of the area, that the Utatúr beds had been disturbed and faulted, probably at the period of upheaval of the granitic band already mentioned, before the deposition of the Trichinopoly formation. Elsewhere also the Trichinopoly beds in places rest upon a denuded surface of Utatúrs. There is also a great change in the fauna. In the southern portion of their range the Trichinopoly beds rest partly upon the coral reefs, which have been already shewn to be some of the lowest beds of Utatúr age, and partly on the metamorphics, a considerable portion of the boundary being formed by the granitoid rock so frequently mentioned already.

The present group, like the Utatúr, is so irregularly bedded, and the dips seen are so frequently those of original deposition, that no trustworthy estimate of the thickness can be formed. The general inclination is to the eastward; the average breadth of the outcrop is nearly the same as that of the Utatúr beds, and the same minimum thickness, *viz.*, 1,000 feet, may be assumed; the general dip of the bedding in the more regularly stratified portion of the group to the northward is, however, lower than in the underlying group, averaging about 6°. The beds thin out greatly to the northward, and are at length completely overlapped by the Arialúrs.

Distribution.—It has already been stated that the Trichinopoly group is confined, so far as is at present known, to the Trichinopoly area. Within that area it forms a second belt east of that formed by the Utatúr group, and extending similarly from south-south-west to north-north-east. The Trichinopoly outcrop is, however, broader in the southern half of the area, where it is about 4 miles across, than in the northern half, where it is in no place more than 2 miles wide. It thins out and disappears completely about 2 miles south of the place where the Utatúrs are similarly overlapped by the Arialúr beds. Along the southern boundary of the Utatúr area, several outliers of Trichinopoly beds are found, resting partly on the Utatúrs and partly on the gneiss, and occasionally overlying the faulted boundaries between the two formations. These small outliers, one of which, south of Tripatúr, forms the south-eastern corner of the whole area, are composed of coarse sands and conglomerates, usually unfossiliferous, but occasionally containing *Chemnitzia undosa* and other characteristic Trichinopoly fossils, and the materials of which they are formed are derived chiefly from the metamorphic rocks, but partly from the denudation of the Utatúr beds.

Palæontology.—The fauna of the Trichinopoly group, although not quite so rich as that of the Utatúr beds, affords a full illustration of the life existing at the period; 186 species of *Invertebrata* having been described from these beds by Dr. Stoliczka. The *Cephalopoda* are comparatively poorly developed, only 23 species having been detected, and of these but 10, of which four are European, are in India peculiar to the group. All the *Cephalopoda* identified belong to the two genera *Nautilus* and *Ammonites*, the non-discoid Ammonitoid genera, such as *Anisoceras*, *Scaphites*, *Turrilites*, &c., so largely represented in the Utatúr group, as well as the *Belemnites*, so abundant in the lower sub-division, being apparently wanting in the Trichinopoly beds. The *Rotomagenses* Ammonites, so characteristic of the lowest cretaceous sub-division in Southern India, are also wanting in the higher groups, with one doubtful exception. A few forms, usually associated with older strata, still survive, however, such as *Ammonites menu*, belonging to the *Armati*, a jurassic group, *A. koluturensis* of the *macrocephalus* group, allied to such oolitic species as *A. macrocephalus* and *A. herveyi*, and *A. theobaldianus*, one of the *Planulati* allied to upper jurassic forms such as *A. biplex*. Most of the types found are, however, characteristically upper cretaceous.

On the other hand, *Gasteropoda*, comprising 86 species, are much more abundant than in the Utatúr group; *Lamellibranchiata* (66 species) being rather less numerous. There are but 5 *Brachiopoda* and 6 corals, whilst no *Echinodermata* have been recognised. The *Gasteropoda* include several siphonostomate genera, rare in the older rocks, and not found in the Utatúr beds; the number increases greatly in the next higher sub-division, that of Arialúr. The whole fauna exhibits a mixture of upper and middle cretaceous forms, and appears fairly to represent the lower chalk of England or the turonian of continental geologists.

The following list of the most important species is similar to that already given from the Utatúr group, an asterisk * denoting the most abundant and characteristic forms, *a* those found in South Africa, and *e* those found in Europe or elsewhere out of Asia:—

CEPHALOPODA.

NAUTILIDÆ—
- *e* * *Nautilus elegans*, middle cretaceous.
- * *N. huxleyanus*.

AMMONITIDÆ—
- *e* *Ammonites subtricarinatus*, middle cretaceous; senonian.
- * *A. sugata*.
- *e* *A. guadaloupæ*, middle cretaceous.
- *A. koluturensis*.
- *e* *A. peramplus*, middle cretaceous; turonian; senonian.
- * *A. planulatus*.
- *e* *A. timotheanus*, gault; grés vert.
- * *A. theobaldianus*.

GASTEROPODA.

ALATA—
* *Pugnellus contortus.*
P. granuliferus.
a P. uncatus.
* *Aporrhais securifera*, Pl. XIII. fig. 5.
e Alaria parkinsoni, gault; greensand.
e A. papillionacea, turonian.
Rostellaria palliata.

CYPRÆIDÆ—
Cypræa (Luponia) newboldi.
C. (Aricia) ficulina.

PLEUROTOMIDÆ—
e Pleurotoma subfusiformis, turonian.

CONIDÆ—
Gosavia indica (perhaps from Arialúr beds).

VOLUTIDÆ—
Scapha attenuata.
e * *Fulguraria elongata*, turonian; cenomanian.
Athleta purpuriformis.
Volutilithes accumulata.
Volutomitra canaliculata.

FASCIOLARIIDÆ—
Latirus reussianus.
a * *Fasciolaria rigida.*

MURICIDÆ—
Hemifusus cinctus.
* *Neptunea excavata.*
e Tritonidea requieniana, middle cretaceous.
a T. trichinopolitensis.
a * *Pollia pondicherriensis.*
Trophon oldhamianum.

PURPURIDÆ·
* *Rapa cancellata.*
Rapana tuberculosa.

TRICHOTROPIDÆ—
e Trichotropis konincki, senonian.

CANCELLARIIDÆ—
Narona eximia.

CERITHIIDÆ—
Cerithium hispidulum.

TURRITELLIDÆ.
Arcotia indica.
* *Turritella (Zaria) brantiana.*
e T. (Torcula) affinis, senonian

LITTORINIDÆ—
Littorina inconstans.
L. acicularis.

RISSOIDÆ—
Rissoa oldhamiana.
Keilostoma politum.

EULIMIDÆ—
a * *Chemnitzia undosa.*
a Euchrysalis gigantea.

NATICIDÆ—
* *Euspira mariæ.*
e * *Ampullina bulbiformis*, turonian; senonian.

TROCHIDÆ—
e Ziziphinus geinitzianus, turonian.

ACTÆONIDÆ—
Bullina alternata.
Actæon seminalis.
A. turriculatus.
Trochactæon cylindraceus.

DENTALIIDÆ—
Dentalium crassulum.

LAMELLIBRANCHIATA.

MYIDÆ—
Corbula parsura.
Poromya superba.

ANATIDÆ—
Corimya oldhamiana.
e Pholadomya caudata, upper and middle cretaceous.
P. radiatula.

SAXICAVIDÆ—
* *Panopæa orientalis.*

SOLENIDÆ—
Siliqua lunata.

TELLINIDÆ—
Tellina (Palæomæra) inconspicua.

VENERIDÆ—
Cyprimeria oldhamiana.
e Eriphyla lenticularis, upper cretaceous.

GLOSSIDÆ—
* *Cyprina forbesiana.*

LAMELLIBRANCHIATA—(*contd.*)

CARDIIDÆ—
Cardium (Trachycardium) incomptum.
e * *Protocardium hillanum*, Pl. XIII, fig. 7, cenomanian to senonian.
Protocardium pondicherriense.

TRIGONIDÆ—
e *Trigonia scabra*, Pl. XIII, fig. 8, upper cretaceous.
T. tuberculifera.
T. semicults.

ARCIDÆ—
* *Trigonoarca trichinopolitensis.*

MYTILIDÆ—
e * *Modiola typica*, turonian.

PINNIDÆ—
Pinna complanata.
P. arata.

AVICULIDÆ—
Inoceramus geinitzianus.

PECTINIDÆ—
e *Pecten (Camptonectes) curvatus*, upper and middle cretaceous.

SPONDYLIDÆ—
Plicatula multicostata.
Spondylus calcaratus.

OSTRÆIDÆ—
e *Ostrea (Alectryonia) diluviana*, middle cretaceous.
e *O. (A.) carinata*, middle cretaceous.

BRACHIOPODA.

e *Rhynconella compressa*, upper cenomanian; turonian.
* *R. plicatiloides.*
e *Terebratula biplicata*, var. *Dutempleana*, middle cretaceous.

ANTHOZOA.

e *Trochosmilia inflexa*, turonian.
e *Isastræa morchella*, turonian.

Arialur group.—The name of the highest group of the South Indian cretaceous series is derived from the town of Arialúr, which lies about 34 miles north-east of Trichinopoly, and 24 miles almost due north from Tanjore, and is situated nearly in the middle of the comparatively large expanse of Arialúr beds in the Trichinopoly district. The country occupied by the beds of this group is much covered with cotton soil, and sections are even rarer than in the two lower cretaceous subdivisions.

The Arialúr beds are more sandy than the two lower groups, and more uniformly bedded, the beds being thick and homogeneous, and consisting principally of white unfossiliferous sands and grey argillaceous sands, with casts of small fossils. Beds of calcareous grit and nodular calcareous shales are found towards the base, and again in the upper portion of the group, and constitute two highly fossiliferous zones, separated by a considerable thickness of deposits, in which fossils are rare or wanting, although some interesting remains of a *Megalosaurus* were found in one of the beds. With the uppermost beds a band of flints is associated. There is a marked difference between the fossils of the upper and lower zones in Trichinopoly, and it appears very probable that further examination of the rocks, now that the fossils have been compared and determined, would justify the separation of this group into

two—a probability which was pointed out by Mr. H. F. Blanford at the time of the original survey, although not shewn on the map, nor applied in the discrimination of the fossils, because of the doubts which remained as to the distinction of the two sub-divisions in the Pondicherry area, where the fossils of both upper and lower Arialúr beds appear to occur together. Conglomerates are of rare occurrence in the Arialúr group, though a coarse bed is found in places near the base, and, except close to the southern boundary, there is but little irregularity in the bedding. The constituents of the Arialúr beds were derived chiefly from the metamorphic rocks, and amongst others from the granitic band to the southward, but a portion of the sediment must have been furnished by the waste of some of the older cretaceous groups, probably the Utatúrs.

The above description of the lithological characters is principally taken from the beds near Arialúr (Trichinopoly district), but it is also to a great extent applicable to the rocks seen near Verdachellam and Pondicherry. In both localities, the Arialúr deposits are chiefly represented by sands or sandy clays, and by beds of arenaceous limestone or calcareous sandstone at the base of the group. The strata appear to thin out to the northward, and it is far from clear whether the uppermost fossiliferous zone extends in that direction, although some of its characteristic fossils, such as *Nautilus danicus*, occur abundantly near Pondicherry. It has not, however, hitherto been found practicable to determine whether a distinct upper zone exists near Pondicherry or whether representatives of the upper fauna occur in beds of lower horizon than those in which the same species are found near Arialúr.

There is consequently some obscurity concerning the relations of the beds belonging to the Arialúr group amongst themselves, and this difficulty is complicated by the circumstance that there is in many places an apparent passage from the Trichinopoly group into the Arialúr beds; the rocks being similar in mineral character near the junction, and the fossils being chiefly forms which appear to range from one group into the other. It is highly probable that further examination of the ground, which, as has been already noticed, is so much concealed by superficial accumulations that the different groups can frequently only be traced by their fossils, would shew that either the number of groups or of palæontological zones must be increased, or else that, in some cases, fossils, supposed to have been procured from the Trichinopoly group, have really been derived from the Arialúr, and *vice versâ*.

Distribution and relations to lower groups.—The area occupied by the Arialúr beds in the eastern portion of the Trichinopoly tract

amounts to about 200 square miles, or more than that covered by both the other sub-divisions together; the outcrop where broadest near Arialúr is about 16 miles wide, and extends for 26 miles from north to south.

The Arialúr beds also occupy the greater portion of a tract 16 miles long by 5 miles broad near Verdachellam, and another about 12 miles long from south-west to north-east, by 2 miles broad, west of Pondicherry, whilst a very small exposure of them occurs close to the coast 10 miles north of Pondicherry, and another still smaller 3 miles farther north.

The lowest fossiliferous zone is found resting upon the Trichinopoly beds throughout the western portion of the Arialúr area in the Trichinopoly district, and the same zone appears to be also represented in the Verdachellam and Pondicherry exposures. The great bulk of the outcrop in all three tracts appears to consist of the thick sands, with but few determinable fossils, forming the middle portion of the formation, whilst the upper fossiliferous beds are only seen north of Arialúr, near the villages of Sainthoray, Ninnyur, and other places farther north, in the long strip of cretaceous rocks forming the north-eastern extremity of the Trichinopoly area, between the Cuddalore sandstones to the east and the alluvium of the Vellaur valley to the west, and extending as far as the Vellaur river about a mile north of Aulathor.

Although the thickness of the Arialúr group can be estimated with a nearer approach to probability than in the case of the two lower cretaceous formations, the estimate is still far from accurate. The dip of the beds is very low, rarely exceeding 2° to 3°, the general inclination being north-east, and the whole of the beds in all probability do not exceed 1,000 feet in Trichinopoly. Near Verdachellam they appear to be very thin, and in the neighbourhood of Pondicherry they are too obscurely exposed for any estimate of their thickness to be attempted. There is an apparent diminution of thickness to the northward as in the other groups, but this attenuation appears to be greatest near Verdachellam, and takes place less rapidly farther north, even if the beds are not thicker in that direction.

The Arialúr beds, as has been already stated, frequently appear to pass into the Trichinopoly group at their base. They, however, overlap the lower groups both to the north and south, and there is, in places, an appearance of unconformity where they rest upon the Trichinopoly beds, nor is it easy to understand the very rapid diminution in the thickness of the latter to the northward without supposing that they had been partially denuded in pre-Arialúr times.

The Arialur beds appear to have been chiefly deposited in a tranquil sea of small depth, although the deposits are less characteristically littoral than those of the Trichinopoly group, and the evidence of the neighbourhood of land afforded by the occurrence of fossil wood is less abundant.

Palæontology.—The invertebrate fauna of the Arialúr group exceeds in richness even that of the Utatúr beds, no less than 365 species having been detected in the uppermost sub-division of the cretaceous rocks of Southern India. The *Cephalopoda* comprise 36 species, *Gasteropoda* 138, *Lamellibranchiata* 117, *Brachiopoda* 12, *Bryozoa* 23, *Echinodermata* 26, *Anthozoa* 10, *Foraminifera* 1, and *Vermes* 2. It is highly probable that this large number may be due partly to the circumstance that the Arialúr deposits comprise two groups differing somewhat in age. The lower fossiliferous beds, from which the bulk of the fossils have been procured, correspond very fairly with the Senonian beds of France and the upper chalk with flints of England. From this horizon all the *Cephalopoda* found in the formation have been derived, with the exception of *Nautilus danicus*, which was only observed in the upper beds of Ninnyur, &c., in the Trichinopoly area, although some specimens were obtained, apparently from a lower horizon, near Pondicherry. The fauna of these upper beds will be noticed separately; the following remarks apply to the remainder of the group.

In the Arialúr beds, as in the lower sub-divisions, there are some forms of *Cephalopoda* which are in Europe characteristic of older beds. These comprise two gault species of *Nautilus*, *N. bouchardianus* and *N. clementinus*, *Ammonites menu*, found also in the lower groups, and

belonging to the Jurassic section of *armati*, *A. velledæ*, a lower and middle cretaceous form in Europe, two *macrocephali*, *A. deccanensis*, and *A. arrialoorensis*, and one of the *Planulati*, *A. theobaldianus*. In the other classes of Mollusca, very few older forms occur, and the great majority of the species common to Europe are found in the upper cretaceous beds of England, France, and Germany.

The most striking peculiarity of the Arialúr fauna is the great abundance of *Gasteropoda*, and especially of the carnivorous prosobranchiate forms, which, as is well known, appear to replace in tertiary and recent seas the *Cephalopoda* of the older periods. Several genera not previously known from cretaceous beds have been detected in the Arialúr group, and the *Cypræidæ* and *Volutidæ* are especially well represented. The *Lamellibranchiata* are also very numerous, whilst all the *Bryozoa* and the great majority of the *Echinodermata* hitherto found in the cretaceous beds of Southern India have been obtained in the highest sub-division. Lower forms of animals are but poorly represented. Amongst the *Vertebrata*, the only important species is a *Megalosaurus*,[1] of which a tooth was found in the middle beds of the deposit, together with a number of bones which, however, could not be extracted in a sufficiently perfect state for determination. The tooth closely resembles that of *M. bucklandi*, found in the Stonesfield slate and Portland oolites of England, and the occurrence of this genus in the upper cretaceous beds of India is of peculiar interest, because in Europe it only ranges from the lias to the wealden. In this instance, as in several others, the land fauna appears to have differed more from that which inhabited distant parts of the earth than the marine fauna did.

The following list of the most important fossils is similar to those of the Utatúr and Trichinopoly groups, and the distinctive marks are the same, an asterisk signifying abundance, and *e* that the fossil occurs also in Europe or elsewhere beyond the limits of Asia :—

CEPHALOPODA.

NAUTILIDÆ—
- *e* *Nautilus bouchardianus*, gault.
- * *N. sphæricus*.
- *e* *N. clementinus*, gault.
- *N. trichinopolitensis*.

AMMONITIDÆ—
- * *Ammonites sugata*.
- *e** *A. gardeni*, upper cretaceous.
- *e* *A. ootacodensis*, upper cretaceous.
- *e* *A. velledæ*, neocomian to cenomanian.
- * *A. arrialoorensis*.
- * *A. madrasinus*.
- *A. theobaldianus*.
- *Helicoceras indicum*.
- *Baculites vagina*.

[1] Mem. G. S. I., Vol. IV, pp. 128, 139; Rec. G. S. I., X, p. 41.

GASTEROPODA.

ALATA—
Rostellaria palliata.
CYPRÆIDÆ—
Cypræa cunliffei.
e *C. kayei*, senonian.
Erato veraghoorensis.
OLIVIDÆ—
Dipsacus vetustus.
DOLIIDÆ—
Oniscia costellata.
PLEUROTOMIDÆ—
Cythara cretacea.
VOLUTIDÆ—
* *Volutilithes septemcostata.*
Turricula arrialoorensis.
FASCIOLARIIDÆ—
Fasciolaria carnatica.
F. assimilis.
MURICIDÆ—
e *Neptunea rhomboidalis*, turonian; senonian.
TRITONIIDÆ—
Hindsia eximia.
Tritonium gravidum.
Lagena secans.
BUCCINIDÆ—
Nassa arrialoorensis.
PURPURIDÆ—
Tudicla eximia.
CANCELLARIIDÆ—
Cancellaria (Euclia) breviplicata, and 3 other species of *Cancellaria.*
CERITHIIDÆ—
e *Cerithium inauguratum*, senonian.
* *C. arcotense.*
e *C. trimonile*, gault.
C. scalaroideum.
C. (Sandbergia) antecedens.
TURRITELLIDÆ—
Turritella (Torcula) pondicherriensis.
e *T. (Zaria) multistriata*, turonian.
SCALIDÆ—
e *Scala subturbinata*, senonian.
VERMETIDÆ—
e * *Burtenella concava*, chalk.
SOLARIIDÆ—
Solarium karapaudiense.
S. vylapaudiense.
LITTORINIDÆ—
Littorina crassitesta.
RISSOIDÆ—
e *Rissoina acuminata*, senonian.
Keilostoma subulatum.
NATICIDÆ—
Euspira pagoda.
VELUTINIDÆ—
Velutina orientalis.
TECTURIDÆ—
Helcion corrugatum.
NERITIDÆ—
Neritina (Velates) decipiens.
Nerita divaricata.
UMBONIIDÆ—
Teinostoma cretaceum.
TROCHIDÆ—
Tectus tamulicus.
e *Ziziphinus geinitzianus*, turonian.
e * *Solariella radiatula*, senonian.
PLEUROTOMARIIDÆ—
* *Leptomaria indica.*
ACTÆONIDÆ—
* *Avellana scrobiculata*, Pl. XIII, f. 6.

LAMELLIBRANCHIATA.

TELLINIDÆ—
Tellina scitulina.
VENERIDÆ—
Cytherea lassula.
GLOSSIDÆ—
Veniella (Venilicardia) obtruncata.
CARDIIDÆ—
Cardium (Trachycardium) exulans.
HIPPURITIDÆ—
Radiolites mutabilis.
CRASSATELLIDÆ—
e *Crassatella macrodonta*, upper cretaceous.
TRIGONIIDÆ—
e *Trigonia scabra*, upper cretaceous.
T. orientalis.

LAMELLIBRANCHIATA—(*contd.*)

NUCULIDÆ—
Nucula crassicula.
ARCIDÆ—
Axinæa subplanata.
* *Macrodon japeticum.*
* *Trigonoarca brahminica.*
T. galdrina.
MYTILIDÆ—
Modiola radiatula.
M. annectans.
AVICULIDÆ—
Avicula (Meleagrina) nitida.
e * *Inoceramus cripsii*, upper cretaceous.
I. simplex.
Melina valida.
RADULIDÆ—
e *Radula (Ctenoides) tecta*, upper cretaceous.
R. (Acesta) obliquistriata.

PECTINIDÆ—
Pecten raduloides.
e *P. (Camptonectes) curvatus*, upper and middle cretaceous.
e *Amusium membranaceum*, upper and middle cretaceous.

SPONDYLIDÆ—
* *Plicatula instabilis.*

OSTRÆIDÆ—
e * *Exogyra ostracina*, upper cretaceous.
e * *Gryphæa vesicularis*, upper cretaceous.
e * *Ostrea (Alectryonia) pectinata*, upper cretaceous.
e * *O. (A.) ungulata*, upper cretaceous.
e *O. acutirostris*, upper cretaceous.

BRACHIOPODA.

e *Crania ignabergenis*, senonian; danian.
Rhynconella plicatiloides.
* *Terebratula subdepressa.*
e *T. biplicata*, cenomanian and turonian.
e *T. subrotunda*, turonian; senonian.

BRYOZOA (*Ciliopoda*).

Cellepora missilis.
Discopora obtecta.
* *Escharinella discors.*
* *Lunulites annulata.*
e *Proboscina radiolitorum*, turonian.
e *P. angustata*, cenomanian.
e *Entalophora lineata*, senonian.

ECHINODERMATA.

Hemiaster tuberosus.
H. indicus.
H. cristatus.
* *Epiaster nobilis.*
* *Stigmatopygus elatus.*
Cassidulus crassus.
Nucleolites pullatus.
e *Galerites* conf. *albogalerus* (*Echinoconus conicus*), senonian.
e *Marsupites milleri*, senonian; upper chalk.

ANTHOZOA.

Cyclolites fæcata.
* *C. filamentosa.*

VERMES.

e *Serpula filiformis*, cenomanian; turonian; senonian.
e *S.* conf. *gordialis*, upper cretaceous.

Uppermost Arialur beds of Ninnyur.—The fauna of the uppermost Arialúr beds found at Ninnyur and other places to the north-east of Arialúr, comprises very few species which are found in the lower portion of the group. Some of the fossils found most abundantly, such as *Nautilus danicus* and *Orbitoides faujasi*, are characteristic in Europe of the uppermost cretaceous deposits of Maestrict, Aix la Chapelle, and the Danish Island of Rügen (Danien of D'Orbigny). No other Cephalopod except *Nautilus danicus* occurs in the Ninnyur beds, whilst the characteristically mesozoic genera *Inoceramus*, *Radiolites*, *Trigonia*, *Trigonoarca*, and *Leptomaria*, which are abundantly represented in the lower portion of the Arialúr group, are entirely wanting in the uppermost fossiliferous zone, where the only important mesozoic genus is *Nerinæa*. On the other hand, however, no typically Tertiary forms make their appearance except carnivorous Gasteropoda, and these are not more numerous in proportion than in the lower zone, although some additional forms are represented.

The following list of the species collected near Ninnyur is probably imperfect. It is taken from the Palæontologia Indica, and some forms, the occurrence of which is especially mentioned by Mr. H. F. Blanford,[1] are omitted. Amongst these are two or three species of *Ovulum* (perhaps, as Dr. Stoliczka pointed out, *Cypreæ*[2] in a peculiar state of preservation), a *Trochus*, and a *Catopygus*. It is probable that some of the specimens collected were not sufficiently well preserved for specific identification, or that they have been overlooked. The distinctive marks are the same as before, with one addition, a dagger † being prefixed to the names of all species found also in the lower zone of the Arialúr group in the Trichinopoly area, or in one of the lower sub-divisions of the cretaceous series in Southern India.

CEPHALOPODA.

NAUTILIDÆ—

e * *Nautilus danicus*, uppermost cretaceous.

[1] Mem. G. S. I., IV, pp. 140, note, 141. That there is some confusion about the fossils from this locality is shewn by the circumstance that in the "Palæontologia Indica," Cretaceous Fauna, Vol. II, p. 221, and again p. 227, *Turritella clicita* and *T. ventricosa* are said to occur at Ninnyur with *Nerinæa blanfordiana*, whilst at p. 184, where *N. blanfordiana* is described, it is only said to be found in the Utatúr group, and no mention is made of the Ninnyur locality. At p. 221 several *Cypræidæ* and *Volutidæ* are mentioned as associated with *Turritella elicita* and *Nerinæa blanfordiana*, but not a single species of *Cypræidæ* is quoted from the locality, and only two species of *Volutidæ*, *viz.*, *Scapha gravida* and *Lyria formosa*.

[2] Pal. Ind., Cret. Faun., Vol. II, p. 47.

GASTEROPODA.

HELICIDÆ—
† *Helix* (*Angystoma*) *cretacea*.
H. (*A.*) *arrialoorensis*.

VOLUTIDÆ—
Scapha gravida.
* *Lyria formosa*.

BUCCINIDÆ—
Pseudoliva subcostata.

PURPURIDÆ—
* *Rapa corallina*.

CANCELLARIIDÆ—
† *Narona eximia?* also found in the Trichinopoly group, the identification of the single Ninnyur specimen somewhat doubtful.

PYRAMIDELLIDÆ—
† *Nerinæa blanfordiana;* also found in the Utatúr group.

TURRITELLIDÆ—
Turritella (*Torcula*) *asperata*.
T. elicita.
T. (*Zaria*) *ventricosa*.

SOLARIIDÆ—
Solarium arcotense.

RISSOIDÆ—
Keilostoma substriatum.

NATICIDÆ—
* *Ampullina sortita*.
e* *Euspira lirata*, turonian; senonian.
Mammilla edura.

ACTÆONIDÆ—
† *Actæon* (*Solidula*) *semen;* found also in the Trichinopoly group.

LAMELLIBRANCHIATA.

GASTROCHÆNIDÆ—
Rocellaria sp. indet.

TELLINIDÆ—
Tellina (*Tellinella*) *arcotensis*.

VENERIDÆ—
Cytherea (*Callista*) *laciniata*, Stol.
C. (*C.*) *discoidalis*.
Cyprimeria obesa.
Eriphyla forbesiana.

CARDIIDÆ—
Cardium (*Cerastoderma*) *pilatum*.

LUCINIDÆ—
Corbis typica.
C. oblonga.
* *Lucina* (*Codakia*) *percrassa*.
† *L. fallax;* found also in the Utatúr group.
L. (*Cyclas*) *tæniolata*.

ASTARTIDÆ—
Cardita jacquinoti.

CRASSATELLIDÆ—
Crassatella zitteliana.

NUCULIDÆ—
* *Nucula indefinita;* found near Pondicherry also.

ARCIDÆ—
† *Axinæa altiuscula*.
Cucullæa æquata.
Barbatia decora.

RADULIDÆ—
Radula interplicosa.

PLACUNIDÆ—
Hemiplicatula detrita.

OSTRÆIDÆ—
e *Exogyra laciniata*, upper cretaceous.
e † *Gryphæa vesicularis*, upper cretaceous.

BRYOZOA.

Membranipora pedata.

ANTHOZOA.

Stylina parvula.
Holocœnia indica.
e† *Astrocœnia decaphylla.* Turonian.
Thamnastræa brevipes.

FORAMINIFERA.

e† *Orbitoides faujasi,* uppermost cretaceous.

Relations between faunas of different groups.—Besides the fossils characteristic of each group, there are a few species which are found throughout the whole series. Of these the most important are the following:—

Nautilus huxleyanus.
e *Ammonites planulatus,* cenomanian; gault.
e *Ampullina bulbiformis,* turonian; senonian.
Gyrodes pansus.
e *Solariella radiatula,* senonian.
e *Vola quinquecostata,* upper and middle cretaceous.

Ammonites menu, Forbes, is also supposed to be found in all three sub-divisions, although there is some doubt about the Utatúr beds, and a rare *Lucina, L.* (*Myrtea*) *arcotina,* has also been procured from all the groups. Some of these fossils, although found throughout the series, are especially characteristic of one sub-division, as in the cases of *Nautilus huxleyanus* and *Solariella radiatula.* A larger number of forms are common to two groups. The following table exhibits the number of each class of *Invertebrata* found in the different formations, and the proportion found also in Europe, or common to two or more groups. The *Vertebrata* are represented by 17 species of fishes and one Saurian, but the remains are of the most fragmentary description, consisting in most cases of single teeth, and it is not certain from which group some of the specimens were originally derived:—

Table shewing the distribution of invertebrate fossils in the cretaceous rocks of Southern India.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Total number of species found in Utatúr group.	Peculiar to Utatúr group in India.	Species included in column 2 found also in Europe.	Total number of species found in Trichinopoly group.	Peculiar to Trichinopoly group in India.	Species in column 5 found also in Europe.	Total number of species found in Arialúr group.	Peculiar to Arialúr group in India.	Species in column 8 found also in Europe.	Species common to Utatúr and Trichinopoly groups.	Species common to Utatúr and Arialúr groups.	Species common to Trichinopoly and Arialúr groups.	Species common to all three groups.	Total species in South Indian cretaceous series.	Total found also in Europe.
Cephalopoda	109	95	25	23	10	4	36	20	5	4	7	6	3	146	38
Gasteropoda	43	36	5	86	59	6	138	113	10	3	1	1	3	237	30
Lamellibranchiata	79	69	8	66	51	5	117	106	10	6	2	7	2	243	29
Brachiopoda	9	8	3	5	2	1	12	8	3	...	1	3	...	21	9
Bryozoa	...	...	...	...	...	...	23	23	4	...	...	...	...	23	4
Vermes	1	1	...	...	...	...	2	2	2	...	...	...	...	3	2
Echinodermata	10	10	4	...	...	...	26	26	4	...	...	...	...	42	8
Anthozoa	42	42	2	6	5	3	10	9	...	...	..	1	...	57	5
Spongiozoa	1	1	1	...	...	...	...	...	...	...	...	...	...	1	1
Foraminifera	...	...	...	...	...	...	1	1	1	...	...	...	...	1	1
TOTAL	294	262	48	186	127	19	365	308	39	13	11	38	8	774	127

Adding the few Vertebrata to the numbers given above, we have a grand total of nearly 800 species of animals from the South Indian cretaceous deposits. Much time was devoted to the collection of the fossils, and their exhaustive examination by Dr. Stoliczka[1] has furnished the best evidence extant for the correlation of any Indian fossil fauna with that of European rocks of corresponding age. Of the whole Invertebrata, 16·36 per cent. consist of forms known to occur in cretaceous beds in Europe. Of these, the great majority are middle or upper cretaceous (cenomanian to senonian); but there are amongst the *Cephalopoda* several forms which in Europe have only been found in lower beds (neocomian and gault), whilst a few are representatives of European jurassic forms, and three species of *Ammonites* belong to a triassic section of the genus. The general facies of the cephalopodous fauna found in the lowest group, that of Utatúr, approximates to that of the European gault, but nearly all the species of the other classes of Mollusca found in the same beds belong to a higher horizon, cenomanian (upper greensand), or even higher.

Physical geography of South India in cretaceous times.—The whole of the cretaceous rocks of Southern India appear to have been formed in shallow water, and in the neighbourhood of a coast line; and it is possible that the relative elevations of the country have undergone but little change since cretaceous times.

Then, as now, there was higher ground to the westward, and the ancient coast line appears to have been approximately parallel to the present, although farther to the west. We have thus in the cretaceous formation a confirmation of the evidence already afforded by the lower mesozoic deposits, that the Indian Peninsula is a land area of great antiquity.

Connexion with cretaceous rocks in other parts of India.—As will be presently shewn, there is a great difference between the fauna of the cretaceous rocks in Southern India and that of the deposits of similar age on the Narbada; but, on the other hand, many of the fossils of the Trichinopoly area are found in the cretaceous rocks of the Khási hills, to the north-east of Bengal, between Assam and Sylhet.[2]

[1] In his account of the *Gasteropoda* and *Lamellibranchiata*, Dr. Stoliczka entered at great length into the question of the general classification of all the genera, recent and fossil, belonging to the families represented in the rocks of Southern India. In the case of the volume devoted to the *Lamellibranchiata* or *Pelecypoda* more especially, a complete list of all genera known, living or extinct, with the typical species in each case, was appended to the Introduction.

[2] These will be described in a separate part of this work. The Khási hills are about 1,200 miles distant from Pondicherry.

So many species are common to the Trichinopoly and Khási deposits, that it is probable that the two regions were part of the same marine area. The cretaceous rocks of the Khási hills are almost unquestionably identical with those extending throughout the hill ranges south of Assam; and the same strata are probably represented in Arakan.

Relations to cretaceous rocks of South Africa.—Before quitting the subject of the Trichinopoly cretaceous beds, it is necessary to notice the very remarkable resemblance between a portion of their fauna and the species found in certain strata in Southern Africa.[1] In the description of the Gondwána system, and again in the account of the upper jurassic beds of Cutch, the remarkable affinities between Indian fossil plants and animals, and the forms found in South African beds, were repeatedly noticed, and there is a similar connexion between the cretaceous formations in the two regions. In some deposits found resting upon Karoo beds on the coast of Natal, out of 35 species of *Mollusca* and *Echinodermata* collected and specifically identified, 22 are identical with forms found in the cretaceous beds of Southern India, the majority being Trichinopoly species. Amongst the South African fossils are *Ammonites gardeni* (Arialúr), *A. kayei* (Utatúr), *Anisoceras rugatum* (Utatúr), *Pugnellus uncatus* (Trichinopoly), *Fasciolaria rigida* (Trichinopoly), *Chemnitzia undosa* (Trichinopoly), *Euchrysalis gigantea* (Trichinopoly and Arialúr), *Solariella radiatula* (all three groups), *Avellana ampla* (Trichinopoly), *Turritella multistriata* (Trichinopoly and Arialúr), *Pecten* (*Vola*) *quinquecostatus* (all three), and *Cardium hillanum* (Trichinopoly) or some of the commonest and most characteristic fossils of the South Indian cretaceous deposits. There is also some slight indication of a representation of the different Indian zones.

The South African beds are clearly coast or shallow water deposits, like those of India, and the great similarity of forms certainly suggests continuity of coast line between the two regions, and thus supports the view that the land connexion between South Africa and India, already shewn to have probably existed in both the lower and upper Gondwána periods, and of which important indications are afforded by the marine jurassic beds, was continued into cretaceous times. It is very surprising to compare the middle cretaceous fauna of Southern India with that of the distant beds of Natal, and then with the widely differing forms found in beds of the same age in Central India and Southern Arabia. The latter will be noticed presently.

[1] Griesbach, Q. J. G. S., 1871, p. 60. Some of the fossils were described by Bailey, Q. J. G. S. 1855, p. 454.

Cretaceous fossils of Sripermatur near Madras.—Amongst the descriptions by Dr. Stoliczka of the cretaceous fossils from Southern India, the following species of *Lamellibranchiata* are included from Sripermatúr, 25 miles west-north-west of Madras, already mentioned as the typical locality for a group of the Upper Gondwána series :—

LUCINIDÆ—
Sphæriola, sp. indet.
UNGULINIDÆ—
Hippagus emilianus.
NUCULANIDÆ—
Yoldia obtusata ?
ARCIDÆ—
Trigonoarca galdrina.
AVICULIDÆ—
Pseudomonotis fullaciosa.
P. inops.
RADULIDÆ—
Limea oldhamiana.
PECTINIDÆ—
Pecten arcotensis.

Two of these, *Yoldia obtusata* and *Trigonoarca galdrina*, are also found in the Arialúr group of the Trichinopoly district, but the identification of the Sripermatúr species referred to the *Yoldia* is slightly open to doubt. *Trigonoarca galdrina* is, however, a well-marked form, and it belongs to a characteristically cretaceous genus.

The specimens were collected by the late Mr. Charles Oldham before the country was properly examined, and there appears some slight doubt as to the precise beds from which they were obtained. Some of the specimens were from Sripermatúr itself, others from Rajah's Choultry. The only cretaceous fossils found by Mr. Foote, who mapped the country in the Sripermatúr neighbourhood, occurred in water-worn blocks of grey or greenish-grey gritty sandstone resting loosely on the surface of jurassic beds near Sripermatúr.[1] The origin of these boulders could not be traced, and the fossils cannot now be found; amongst the forms obtained were four or five species of *Ammonites*, some *Belemnites*, &c.

Cretaceous beds of the Narbada valley or Bagh beds.—The marine cretaceous formations found in the western portion of the Narbada valley have been commonly known as "Bágh beds," from the town of Bágh, which is situated about 90 miles west by south of Indore, and 35 miles west-south-west of Dhar. The town is not on cretaceous rocks, though they are well developed in the neighbourhood. The occurrence of cretaceous fossils near Bágh was discovered by Colonel Keatinge[2] in 1856, but the existence of fossiliferous limestone in this part of the Narbada valley had been known for a long time, although the exact locality had not been ascertained. The circumstance that blocks of limestone, containing fragments of *Bryozoa* and other fossils, had been employed in building the houses of Mándu (Mándoo), a city now in

[1] See Mem. G. S. I., X, p. 61. [2] J. A. S. B., 1858, XXVII. p. 116.

ruins, about 20 miles south of Dhár, first attracted attention, and it was mainly owing to an ingenious and happy suggestion of Dr. Carter's[1] that attention was attracted to the neighbourhood of Bágh, where limestone had been observed in 1818 by Captain Dangerfield.

The cretaceous rocks of the lower Narbada valley[2] occur chiefly along the edge of the Deccan traps, and intervene between the latter and the metamorphic rocks. West of Bágh the outcrop of the cretaceous beds may be traced with a few interruptions to the neighbourhood of Baroda. East of Bágh, they only occur in places around the inliers of older rocks, and in this direction they appear to pass into the unfossiliferous Lameta group, which will be described in a subsequent page in connection with the Deccan traps.

Mineral characters and distribution.—As a general rule, the Bágh beds are composed of a calcareous rock above and of sandstone below, but the character of each portion of the formation varies. Commencing to the eastward, the first place where marine cretaceous beds are known to occur is in the neighbourhood of Barwai, on the Narbada, nearly due south of Indore. Here some conglomerates, more or less calcareous, and sandstones containing marine shells, represent the cretaceous formation, and in one place are seen to be distinctly unconformable to an outlier of Maháideva conglomerate belonging to the upper Gondwána series.[3] From the neighbourhood of Barwai the whole Narbada valley is composed of trap for nearly 50 miles to the westward. Lower rocks reappear near Mándú, between which place and Bágh the cretaceous beds are found, forming a narrow fringe to the traps, around several inliers of Bijáwar and metamorphic rocks. The general descending section of the Bágh beds near Cherakhan, 22 miles east of Bágh, is the following:—

	Feet.
Coralline limestone	10 to 20
Argillaceous limestone, fossiliferous, about . . .	10
Unfossiliferous nodular limestone	20
Sandstone and conglomerate	20

The so-called coralline limestone is the rock of which Mándú was built, and to which reference has already been made; it is yellow or red in colour (the former tint being doubtless due to some carbonate of iron, in the limestone exposed to the air, being converted into peroxide), and consists chiefly of small fragments of *Bryozoa*, shells, &c. The

[1] Jour. Bom. Br. R. A. S., V, p. 238.

[2] For a more complete description, see Mem. G. S. I., VI, pp. (207)-(219), (264), (294), (323), &c.

[3] For additional details, see Rec. G. S. I., VIII, p. 72.

freshly broken surface has a somewhat granular mottled appearance, and the fossils are not conspicuous; they weather out on exposure. In many places this bed is obliquely laminated. Beneath it, is an impure argillaceous limestone from which all the fossils of the Bágh beds hitherto procured in this neighbourhood have been obtained. They are chiefly Echinoderms, *Hemiaster* being the prevalent genus. These two bands of limestone are only found in the neighbourhood of Cherakhan, and neither has hitherto been found west of Bágh.

The nodular limestone and the sandstone are more extensively developed. At Bágh itself from 15 to 20 feet of the limestone rest upon 80 or 100 feet of sandstone. The limestone is nearly unfossiliferous, only here and there a fossil occurs in it, and the few specimens found are but rarely well preserved. The sandstones are fine or coarse, white and purple in colour, and frequently conglomeratic. Sometimes they are shaly or calcareous.

West of Bágh, the cretaceous rocks occupy a considerable area, their outcrop being nearly 15 miles broad, and their thickness, especially to the southward, must be much greater than at Bágh. Farther to the westward, they form a fringe of varying width along the northern edge of the trap, and they also appear in several inliers within the trap boundary. At Alli (Allee), 30 miles west-south-west of Bágh, a section is exposed exhibiting 150 to 200 feet of sandstone, on which rests conglomerate, capped by limestone, with a few corals, echinoderms, &c. The largest expanse of the cretaceous beds to the westward is on the edge of the alluvium of Guzerat, near the village of Talukwára, 35 miles south-east of Baroda. Here they cover a tract lying just north of the Narbada river, and about 15 miles long from north by east to south by west, by 6 or 7 miles broad. About 10 miles to the south-east, south of the Narbada, there is a large inlier, about 6 miles from north to south and 10 from east to west, entirely composed of cretaceous rocks, of which good sections are exposed in the Deva stream, a tributary of the Narbada. The base is not seen, but a thickness of at least 1,000 feet of cretaceous rocks is exposed, and here, as in the tract near Talukwára, the upper portion consists of dark-coloured shales, more or less calcareous, and not unfrequently containing oysters, whilst the lower portion is composed of coarse sandstones and conglomerates. The shales in the Deva inlier are 500 feet thick.

One peculiarity of the uppermost calcareous beds is the frequent occurrence in them of cherty or flinty masses. This character causes the beds closely to resemble the Lameta or infratrappean rocks, and it may in both cases be due to the same cause—infiltration of silica from the overlying trap.

Physical geology.—Throughout the area of the cretaceous rocks on the Western Narbada there is a constant tendency to increase in thickness to the southward. To the north, the Bágh beds are represented by a thin band frequently not more than 10 or 15 feet thick, of coarse sandstone and conglomerate. To the south, as just noticed in the Deva valley, these strata are at least 1,000 feet thick. It is true that a great part of this thickness consists of sandstone, and the suggestion has already been made[1] that this sandstone may belong to the Mahádeva series, but the two facts, that no unconformity has been detected between the calcareous shales, which are certainly cretaceous, and the underlying sandstone, and that both formations increase similarly in thickness to the southward, are strongly in favour of referring both to the same age.[2]

As a rule, the cretaceous rocks near Bágh are but little disturbed. More to the westward they have in general a low dip to the south, as have also the overlying traps. The cretaceous strata rest unconformably upon old metamorphic and Bijáwar beds, and the only instance in which they have been observed in connexion with older beds of later date than the transition series is that already mentioned near Barwai. The relations between the Bágh cretaceous rocks and the Deccan traps will be described when treating of the latter series.

Palæontology.—No large collections of fossils have been procured from the beds of Bágh, and of those obtained, many are ill preserved, and the majority have not as yet been determined. Some fragmentary *Ammonites* and *Belemnites* have been found, but the only common fossils besides oysters are Echinoderms, *Pecten (Vola* or *Janira) quadricostatus*,[3] and a few other bivalves; a *Rhynconella* is also found. The following fossils were determined by Prof. Martin Duncan[4] :—

LAMELLIBRANCHIATA—
Neithea alpina.[5]
Pecten (*Vola*) *quadricostatus*.
BRACHIOPODA—
Rhynconella depressa.
BRYOZOA—
Escharina, sp.
Eschara, sp.

VERMES—
Vincularia, sp.
Serpula plexus.
ECHINODERMATA—
Hemiaster cenomaniensis.
H. similis.
Echinobrissus similis.
E. subquadratus.
CORALLIA—
Thamnastræa decipiens.

[1] *Ante*, page 221.

[2] The Mahádeva beds, it should be remembered, are supposed to be of Jurassic age.

[3] This is said by Dr. Stoliczka to be probably identical with *Pecten* (*Vola*) *quinque-costatus*, Pal. Ind., Ser. VI, Cret. Faun., III, p. 438.

[4] Q. J. G. S., 1865, XXI, pp. 353 and 354.

[5] According to Dr. Stoliczka, Pal. Ind., Ser. VI, Cret. Faun., III. pp. 426, 438, *Neithea* is identical with *Vola* and *Janira*, and *N. alpina* but doubtfully distinct from *Vola* (*Pecten*) *quinque-costata*.

Some of the species have a wide range in time amongst the cretaceous rocks of Europe, but all occur in the upper greensand (cenomanian), many being characteristic forms, and the cretaceous rocks of the Narbada valley must in consequence closely correspond to the Utatúr group of Southern India. It is curious to note that, so far as is known, only one species, *Pecten* (*Vola*) *quinquecostatus*, is common to both, and even in this case the identification depends upon a question as to which palæontologists are not thoroughly agreed. The species moreover is one of wide range both in time and space. *Hemiaster similis* and *H. cenomaniensis* are remotely allied to *H. rana* (Arialúr) and *H. expansus* (Utatúr) of the Southern Indian cretaceous deposits, and *Thamnastræa decipiens* is replaced in the Utatúr beds by a closely allied form, *T. hieroglyphica*, Stol.

Relations to cretaceous fauna of Southern Arabia.—In strange contrast with the wide difference between the known fauna of the Bágh beds and that of the Southern Indian deposits is the similarity between the fossil remains of the Narbada valley and those found in two localities, Ras Fartak and Ras Sharwen on the south-east coast of Arabia.[1] The collections examined from both localities are small, and were obtained in each case during a short visit; but although the united Arabian collections only comprise 13 species and the Bágh 12, three of these, *viz.*, *Hemiaster similis*, *Vola quadricostata*, and *Neithea alpina*, are common to the two countries.

The cretaceous beds of the lower Narbada valley are about 750 miles distant from those of Southern India, and twice as far from the Arabian localities. The marked contrast between the fossil fauna in the one case, and the similarity in the other, tend to suggest the probability that a land barrier interposed in middle cretaceous times between Southern India with Assam and Arakan on the one side and the Western Narbada region with the south coast of Arabia on the other. We have thus another argument presented to us in favor of the Indian Peninsula being the portion of an ancient land area; and taking into consideration the marked connexion between the faunas of the South Indian and South African cretaceous deposits and the circumstance that both appear to be of littoral origin, it is probable that this land area extended to Africa.

[1] See Prof. Martin Duncan's paper in the Quart. Jour. Geol. Soc. already quoted; 1865, pp. 352 to 354, &c. The Arabian localities were originally described and the fossils collected by Dr. Carter (Jour. Bom. Br. R. A. S., Vol. IV, p. 71, and geological papers on Western India, pp. 603, &c.).

At the same time the coarseness of the Narbada cretaceous rocks shews that they must have been deposited in the neighbourhood of a coast, and their rapid increase in thickness to the southward renders it likely that land existed to the north. On the whole, it is most probable that they were formed in a bay or inlet, open to the westward and closed to the eastward, in which direction beds of similar character, but apparently of fresh water origin, are found occupying the same position at the base of the Deccan traps.

CHAPTER XIII.

PENINSULAR AREA.

DECCAN TRAP SERIES.

Area occupied and original limits — Name of series — Scenery and vegetation of trap area — Petrology — Volcanic ash — Minerals, original or of secondary origin — Horizontality of traps — Thickness of lava flows — Sedimentary beds associated with traps and classification of series — Whole thickness of series — Lameta group — Relations to older formations — Distribution — Fossils — Intertrappean beds of Nágpúr, the Narbada valley, &c. — Fossils of the lower intertrappeans — Marine beds, associated with trap near Rájámahendri — Infratrappean — Intertrappean beds of Rájámahendri — Fossils — Upper intertrappean beds of Bombay — Fossils — Origin of the Deccan traps subaërial — Relations of Deccan traps to underlying rocks — Subaërial origin of traps proved by occurrence of fresh-water beds — Lower traps not poured out in a great lake — Horizontal traps difficult to explain — Volcanic foci — Geological age of the Deccan traps — Probable conditions prevailing during Deccan trap epoch.

Area occupied and original limits.—In contradistinction to the formations described in the last few chapters, the great volcanic series[1] of India is one of the most prominent and widely spread of all the rock systems found in the Peninsula. In superficial area the Deccan traps are only exceeded within the limits of peninsular India south of the Indo-Gangetic plain by the metamorphic series, and although the traps are far inferior in thickness to the Vindhyan and Gondwána formations, their remarkable horizontality throughout a great part of the region covered by them enables them to conceal all older rocks. Some faint idea of the extensive area occupied by this formation may be gained from the fact that the railway from Bombay to Nágpúr, 519 miles long, never leaves the volcanic rocks until it is close to the Nágpúr station, and that the traps extend without a break from the sea-coast

[1] This series has been described more or less fully by numerous geological writers, especially Sykes (Geol. Trans., Ser. 2, Vol. IV, p. 409), Malcolmson (*id.*, Vol. V., p. 537), Carter (Jour. Bombay Br. R. A. S., Vol. V, p. 255, &c.), and Hislop (Q. J. G. S., 1855, p. 356; 1860, p. 154).

For further details and references, the following parts of the "Memoirs of the Geological Survey of India" may be consulted:—Vol. II, p. 217; VI, pp. (137), (219), &c.; IX, pp. (58), (318); X, p. (178); and XII, p. (171); also Records, G. S. I., I, p. 60; V, p. 115.

at Bombay (longitude 72° 51′ east to Amarkantak at the head of the Narbada (longitude about 82° east), and from near Belgaum (latitude 15° 35′ north) to north of Goona (latitude 25° north). Even this extent, great as it is, by no means represents the whole area originally occupied by the formation, for outliers are found east of Amarkantak as far as Jumera Pat in Sirgúja (longitude 84° east), and to the south-east a small outcrop occurs close to Rájámahendri, whilst to the westward the series is well developed in Kattywar (Kathiawad) and Cutch (Kachh), and it has even been found represented, though by two very thin bands, west of Kotri in Sind (latitude 68°). To the north and south the evidence of the original limit is imperfect; we have, however, proof of the existence of this volcanic formation throughout nearly ten degrees of latitude and sixteen of longitude, whilst the area covered in the Peninsula of India can be little less than 200,000 square miles. It is probable that the limits mentioned very nearly correspond to the original boundaries of the volcanic rocks, because the high level laterite, which rests conformably upon the uppermost traps of the Deccan, is found to the southward, eastward and northward, overlying rocks older than the volcanic series, and if, as will be shewn to be probable in a later chapter, this laterite was formed at a date immediately subsequent to the cessation of the igneous outbursts, it may be inferred that the lava flows never extended to the localities (such as Gwalior, Rewah, Bastar, &c.) in which the laterite is found resting immediately upon Vindhyan, transition, or metamorphic rocks.

Malwa Ghats from the Narbada valley, near Mahesar.

Name of series.—In adopting the name of "Deccan[1] trap" for this great volcanic formation, the Geological Survey has been guided partly by old usage, partly by the circumstance that the term "trap" was originally applied to similar horizontally stratified lava flows. Some geologists have condemned the term on account of the loose manner in which it has been used for a great variety of igneous rocks, but it is difficult to replace it, and in the present case, at all events, it is employed in a well defined sense.

Scenery and vegetation of trap area.—In consequence of its geological structure, the volcanic region of Central and Western India is distinguished by marked peculiarities of scenery, and the characters of the surface are widely different from those found in other parts of the Indian Peninsula. Great undulating plains, divided from each other by flat-topped ranges of hills, occupy the greater portion of the country; and the hill-sides are marked by conspicuous terraces, which may often be traced for great distances, and are due to the outcrop of the harder basaltic strata, or of those beds which resist best the disintegrating influences of exposure. In some parts of the area great scarps are found, some of those in the Sahyádri range being 4,000 feet in height, all conspicuously banded with horizontal terraces. Examples of the ordinary scenery of the trap region are shewn in the accompanying woodcuts.

Hill composed of Deccan trap, near Harngaon, north of Nimawar, Narbada valley.

The vegetation of the trap area differs no less conspicuously from that which is found on other formations; the distinction in the dry

[1] It is scarcely necessary to state that the Deccan comprises that part of the Indian Peninsula which is south (*dakhin*) of the Vindhyan range.

season being so marked that, especially when taken in connexion with the form of the surface, it enables hills and ranges of trap to be distinguished at a distance from those composed of other rocks. The peculiarity consists in the prevalence of long grass and the paucity of large trees,[1] and in the circumstance that almost all bushes and trees, except in the damp districts near the sea, are deciduous. The result is, that the whole country, except where it is cultivated, presents during the cold season, from November till March, a uniform straw-coloured surface, with but few spots of green to break the monotony; whilst from March, when the grass is burnt, until the commencement of the rains, in June, the black soil, black rocks, and blackened tree stems present a most remarkable aspect of desolation. During the rainy season, however, the country is covered with verdure, and in many parts it is very beautiful, the contrast afforded by the black rocks only serving to bring into relief the bright green tints of the foliage.

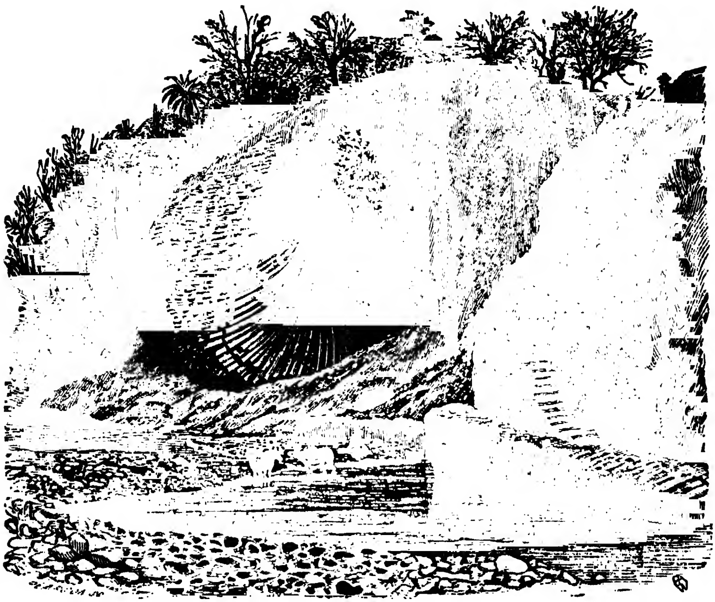
Petrology.—Throughout the trap area the prevailing rock is some form of dolerite or basalt,[2] but there is a large amount of variation in the characters presented by different beds. Some are excessively compact, hard, and homogeneous, the crystalline structure being so minute as to be detected with difficulty (anamesite); others are coarsely crystalline, and these frequently contain olivine in considerable quantities; and one variety is porphyritic, and contains large tabular crystals of glassy felspar, white or green in colour. Many of the basalts again are soft and earthy, evidently in most cases, and probably in all, from partial decomposition. The most striking peculiarity is, perhaps, the great prevalence of amygdaloid, in which the nodules, chiefly containing zeolite or agate, sometimes form the principal part of the rock. These nodules are very often coated with glauconite (green earth), and the prevalence of this mineral is highly characteristic. Almost throughout their range, the Deccan traps may be recognized by the occurrence of the amygdaloidal basalts with green earth, or of the porphyry with crystals of glassy felspar.

Exfoliating concretionary structure is common in the softer forms of basalt, which have undergone some amount of decomposition, but it is

[1] The want of large trees is partly due to the wanton destruction to which the forests of India have been exposed for ages through reckless cutting, to equally reckless clearing for temporary cultivation of a rude kind, and, perhaps, more than all, to the practice of annually burning the grass at the commencement of the hot season.

[2] The meaning in which these names of rocks are used will be explained in the glossary at the end of this work. So far as is practicable, the terms are employed in the sense in which they are accepted by English geologists generally. A well-known German school of which Professor Zirkel and Baron von Richthofen are distinguished exponents, and which holds views, not admitted by English geologists, as to the limitation of different kinds of volcanic rocks to particular geological horizons, adopts the same terms with a somewhat different acceptation.

never seen in the hard compact beds. Frequently the hard unaltered spheroidal cores of concentric nodules are to be found scattered over the surface of the bed, from which they have weathered out, and they may easily be mistaken for rolled fragments. Columnar structure is less common, though it is occasionally seen, a fine example being shewn in the following woodcut. In some cases this structure has been observed in



Radiating basaltic columns; in a dyke near Gújri, north-west of Mahesar, Narbada valley.

the compact basaltic flows; it is frequently seen in the lowest flow, a very thick one, in the Narbada valley, west of Hoshangabád, and in one of the lower flows in Málwa, but the appearance is often confined to intrusive dykes, as in the example illustrated. Trachytic rocks are extremely rare, and have hitherto only been found in intrusive masses.

Volcanic ash.—Beds of volcanic ash are common, so common indeed in places as to form a very considerable proportion of the strata, and they appear to be much more prevalent towards the upper part of the series.[1] They often differ but little in appearance from the basaltic lavas with which they are interstratified, but on close examination

[1] This may be due to the circumstance that the upper part of the series is chiefly preserved in localities which were near the old volcanic foci. Ashes are found interstratified with the lower beds on the Narbada, west of Baroda, where remains of ancient volcanic cores also occur.

their brecciated structure can always be readily detected, and the blocks of scoriæ which they contain generally weather out on exposed surfaces and remain in relief, precisely as on old volcanic cones. Magnificent examples are to be seen on most of the higher portions of the Sahyádri or Western Ghát range, and on the high peaks, formerly used as hill forts, around Poona; well-marked instances occur also in Bombay and Salsette.[1] Very frequently a thin bed of ash intervenes between two basaltic flows. Occasionally pumice is found in the ash beds, the interstices, however, being all filled up by the same process as that by which vesicular lava has been converted into amygdaloid. Here and there, throughout the traps, beds of red bole occur; they are usually only a foot or two thick, but occasionally more. Sometimes the bole contains scoriæ; and in this case it frequently covers the upper surface of a basaltic flow, into which it appears to pass. In some instances the bole is so uniformly stratified that it has the appearance of having been deposited from water.[2]

In a few instances bands of very homogeneous structure and of a pale lilac colour, formed of an apparently argillaceous rock, resembling bole in texture, and so perfectly laminated as to exactly simulate shale, have been found interstratified with the basalts. This is especially the case at a large hill called Powagarh, 2,000 feet high, near Baroda, and similar beds are said to occur in Kattywar; they have also been noticed east of Surat. The occasional occurrence of glassy felspar crystals in these beds and the circumstance that some of the harder basalts at times weather on their exposed edges into a somewhat similar soft lilac rock, render it possible that these shaly strata result from the alteration of trap. At the same time it is far from improbable that some of them may be consolidated volcanic mud, composed of fine lapilli washed down and deposited by water.

Minerals, original or of secondary origin.—Amongst the original mineral constituents of the doleritic lavas, but few are sufficiently

[1] Amongst the best examples are the rock in which the Kanheri caves of Salsette are cut, some beds on the Kamatki ghât between Poona and Maháblesbwar, and a conspicuous bed at the lower gateway of the fortress of Sinhgarh near Poona. Ash-breccias also occur in Bombay Island at Flag-staff hill and Rai hill, Parel, and in the neighbourhood of Sion Fort. It must not be supposed from these examples that the rock is rare. It is found almost throughout the trap country, but it is much less common towards the base of the traps.

[2] Sir C. Lyell has shewn that bands of red clay interstratified with the lavas of Etna have been formed from the crust of the lower lava flow decomposed into clay and then baked and reddened by the heat of the overlying flow, or where "volcanic sand has been showered down from above and washed over the older lavas by torrents and floods," Phil. Trans., 1858, p. 711. Similar beds appear to be characteristic of subaërial lava flows; Judd, Q. J. G. S., 1874, XXX, p. 227. See also p. 365.

distinct for recognition; no crystallised pyroxene has been observed except locally in some of the ash beds, and the only felspar which occurs in distinct crystals appears to be the form of orthoclase (glassy felspar) which is found in the porphyritic rock already mentioned. Olivine and magnetite are common, the former occurring as translucent yellowish grains, the latter in minute crystals, too small, as a rule, to be recognised by the naked eye, but easily detected, if abundant, by the effect of the rock upon the magnetic needle. Magnetic iron sand derived from the traps is frequently found in the streams which traverse the rocks. With the tabular felspar crystals small scales of red mica are found.

Secondary minerals of various kinds, which have been formed since the consolidation of the volcanic strata, are found in the greatest abundance in some of the flows, especially in the amygdaloidal, and in some of the more earthy and decomposed traps. These minerals not only form the nodules of the amygdaloid, but they are found lining cracks and hollows, the finest crystals being always in geodes or cavities, some of which are as much as two or three feet across, and even larger hollows lined with crystals are said to have been found. The commonest minerals are quartz, either crystaline or in the form of agate, bloodstone, jasper, &c. and *Stilbite*, next in abundance are *Apophyllite*, *Heulandite*, *Scolecite* (*Poonahlite*), *Laumonite* and *Calcite*: *Thomsonite*, *Epistilbite*, *Prehnite* and *Chabasite* also occur, but they are rare.[1] The great prevalence of *Glauconite* or green earth has already been noticed.

The crystalline quartz is occasionally, though rarely, amethystine; it but seldom occurs in crystals which exceed an inch in diameter, and the larger crystals are not often transparent. The form known as trihedral quartz, in which the terminal pyramid of each quartz crystal consists of three planes instead of six, or in which three planes are very much more developed than the other three, is of common occurrence. The agates occur chiefly in geodes or nodules, large and small; many are finely banded, and, after being coloured by heating, are cut into ornaments.[2] Jasper and heliotrope or bloodstone occur chiefly in flat plates which appear to have been formed in cracks, and agate is sometimes met with of apparently similar origin. *Stilbite* is very common, though less so than quartz; one magnificent variety consists of large orange or salmon

[1] Two other mineral species besides poonahlite have been described from the Deccan traps. One of these is *Hislopite* (Haughton: Phil. Mag., 1859, Vol. XVII, p. 16) which appears to be calcite coloured by glauconite (green earth) and the other *Syhedrite* (Shepard; Am. Jour. Sci., July 1865, Vol. XL, p. 110) is stilbite coloured in the same manner.

[2] Most of the stones cut for ornaments are either procured from rivers or from the tertiary graavls derived from the denudation of the traps.

coloured crystals, often 2 or 3 inches in length, usually compound or in sheaf-like aggregations, but occasionally in large flat prisms terminated by a four-sided pyramid. *Apophyllite* is the finest of all the Deccan trap minerals. It generally occurs in four-sided prisms with terminal planes, a form which closely resembles the cubical crystals of the isometric system; the double pyramid, with replacements of the secondary prismatic faces and terminal planes, so characteristic of this mineral in other localities, being chiefly typical of small crystals in the Deccan traps. The colour of the Deccan apophyllite is usually white, more rarely pink or green; some crystals are perfectly transparent, and one of the most magnificent associations of minerals to be found anywhere is seen when, as occasionally happens, perfectly clear vitreous crystals of apophyllite, of large size, are inserted on a mass of orange stilbite. Some apophyllite crystals are as much as 3 and 4 inches across. The other minerals are less deserving of notice, but very beautiful long acicular crystals of scolecite with exquisitely formed pyramidal terminations are of occasional occurrence, and fine crystals of white heulandite are not unfrequent. The glauconite is usually amorphous, but occasionally forms an aggregate of crystalline scales, and a massive mineral which, if not green earth, is closely akin both in appearance and composition, occasionally occupies small cavities completely.

Horizontality of traps.—One of the most remarkable characters of the Deccan traps is their persistent flatness or near approach to horizontality throughout the greater portion of their area. This is conspicuous throughout the Sahyádri range, over the whole of the Bombay Deccan, from Khandesh to Belgaum and Sholapúr, throughout Southern Berar and the north-western portion of the Hyderabád territory, in many parts of the Sátpura range between the Narbada and Tapti, and on the Málwa plateau north of the Narbada. Where exceptions occur, as in the Western Sátpúra and Rájpipla hills, and along the coast near Bombay, the disturbance is shewn to be of later date from its affecting contemporaneous or newer beds of sedimentary origin. The only departure from absolute horizontality to be seen in the lava flows of the Deccan is frequently no more than may be due to the lenticular form of the beds, but usually there is a very low dip discernible, seldom exceeding 1°, and fairly constant over large areas. This circumstance tends to shew that even this small amount of inclination may be due to disturbance, because if the dips represented the original angle at which the lava flows were consolidated, they would be found to radiate from the original volcanic vents. Nothing of the kind has, however, been traced.

Thickness of lava flows.—The separate lava flows are, as a rule, of no great thickness. The average in the two sections of the Bor and Thul Ghâts, measured on the railway lines, is apparently 64 and 87 feet respectively, but really less, because the distinction between the flows can in most cases only be recognised by lithological characters; and where, as must frequently be the case, two or more beds of similar appearance and composition occur together, they must often be confounded and measured as one. Many of the more amygdaloidal beds appear to be made up of several smaller flows from 6 to 10 feet thick, distinguished by being highly amygdaloidal above, less so in the middle, and traversed towards the base by long cylindrical, vertical pipes filled with zeolite.[1] But even supposing that these apparent distinctions are accidental, some well-marked crystalline flows in each section do not exceed 15 feet in thickness.

Associated sedimentary beds and classification of series.—Hitherto only the igneous portion of the Deccan series has been described, but volcanic rocks, although they form the great mass of the formation, do not compose it exclusively; for sedimentary bands, frequently fossiliferous, have been found in several places interstratified with the lava flows, and have become widely known and described as *intertrappean beds*. At the base of the whole series also there is found, in many places, a small group of limestones, sandstones and clays, known as the *Lameta group*, from its occurrence at Lameta Ghât, on the Narbada, near Jabalpur. Formerly this Lameta group was supposed to be an eastern representative of the Mahádeva formation (Gondwána), but further examination has shewn that the Mahádevas are much more ancient, and that the Lameta beds are so closely associated with the lowest trap that they must be considered as part of the same series. It has also been determined that intertrappean beds occur in two distinct portions of the Deccan series; first, close to the base, throughout the greater portion of the enormously extensive circuit of the volcanic area; and, secondly, in the highest portion of the traps, only known to occur close to the coast in Bombay Island and the immediate

[1] Bearing in mind that amygdaloidal basalt must have been originally vesicular lava, and that what are now nodules of quartz or zeolite were originally air or steam bubbles, it is easy to understand that the upper portion of a lava flow must have been more vesicular originally than the lower portion, and hence that a prevalence of amygdaloidal structure would be characteristic of the upper part of a flow. The vertical tubes must also have been originally filled with air or vapour, perhaps expelled from the underlying stratum by the heated mass flowing over it after it had been cooled and consolidated.

neighbourhood.[1] A rough classification of the whole series is presented in the following section :—

	Approximate[2] thickness in feet.
1. Upper traps, with numerous beds of volcanic ash and the intertrappean sedimentary deposits of Bombay . .	1,500
2. Middle traps, ash beds numerous above, but less frequent towards the base, no sedimentary beds known . .	4,000
3. Lower traps, with intertrappeans of Nágpur, Narbada valley, &c., volcanic ash of rare occurrence or wanting .	500
4. Lameta or infratrappean group	20 to 100

Whole thickness of series.—The whole thickness, as will be shewn presently, is probably considerably greater than 6,000 feet in the neighbourhood of Bombay, but the rocks gradually thin out in other directions. At Bombay the upper limit of the series is not seen. It is highly probable that near Surat and Baroda the trap may have been even thicker than near Bombay; but, as will be shewn hereafter, the upper portions have been greatly denuded, and it is extremely difficult here, as in most other places, to estimate the thickness with any accuracy. In Kachh (Cutch) the traps are about 2,500 feet thick, whilst in Sind they have dwindled down to two bands at different horizons, each less than 100 feet thick. Throughout the greater portion of their area, no higher beds except laterite or post-tertiary deposits are found resting upon them, and it is impossible to form any accurate estimate of their original development. In the extreme south of the volcanic area, near Belgaum, their thickness has been estimated by Mr. Foote to be 2,000 to 2,500 feet; on the plateau of Amarkantak, at the eastern extremity of their main area, they are about 500 feet thick, but farther east in the outlier on Main Pat in Sirgúja, not more than 300 to 400, whilst to the south-east near Rájámahendri they are represented by a thin outlier, in which from 100 to 200 feet of basalt may be exposed.

Lameta group.—Before proceeding further it will be necessary to give a fuller description of the sedimentary formations, and in accordance with the system adopted throughout this work, the Lameta group as the lowest will first receive attention.[3] The origin of the name has already been mentioned, and it has been stated that the group consists

[1] The reasons for considering the Bombay traps higher in the series than the others will be explained subsequently, when the intertrappean beds are described.

[2] The thickness given is little more than a guess, except in the case of the lower traps and Lametas. The other figures are minimum estimates of the vertical extent of the series where fairly developed.

[3] For further information, see Hislop: Q. J. G. S., 1860, p. 154; also Mem. G. S. I., II, p. 196; VI, p. (216); IX, p. (315); XIII, p. 87; and Rec., G. S. I., V, pp. 88, 115.

of limestones, sandstones and clays. The limestones are the most characteristic and persistent beds; they frequently occur alone, and they form the upper portion of the group, when other beds are associated with them. Occasionally the limestone is pure, but it is commonly full of sand and small pebbles, so as to form a calcareous grit rather than a limestone, and it abounds as a rule in masses, sometimes irregular, sometimes more or less lenticular in form, of segregated chert. Some of the small pebbles frequently consist of red jasper, the occurrence of which is very characteristic. This gritty limestone with its included chert nodules is found over a very extensive tract of country in the Central Provinces, and appears to be rarely absent throughout any large area in which the base of the traps is exposed. It is precisely similar in mineral character to the uppermost band of the Bágh beds, and the resemblance between the two, together with their position at the base of the traps, renders it probable that both may be of the same age. The occurrence of the chert nodules may be due in both cases to infiltration from the overlying traps, or to deposition from hot springs at the commencement of the volcanic epoch,[1] but the similarity of mineral character exists independently of the association of silica.

The bed which, after the limestone, is most commonly found in the Lameta group, is a rather fine porous earthy sandstone, usually of a greenish colour. The clays are red or green, and are very frequently sandy or marly; sometimes they contain nodular carbonate of lime. They are of local occurrence and appear but rarely to extend over any considerable area. All these beds pass into each other; the limestone is not unfrequently merely the sandstone cemented by carbonate of lime, the marls are an argillaceous form of the limestone, and except where the characteristic gritty limestone is the sole representative of the formation, there is, as a rule, a frequent change of character in the beds, both horizontally and vertically. This is usually the case where the thickness exceeds 20 or 30 feet; where the group is represented by a thin band, either the gritty limestone or the earthy greenish sandstone is commonly found alone.

Relations to older formations.—The Lameta group is quite unconformable to all the various older formations upon which it rests, from the metamorphics to the Jabalpur group. As a rule the lowest flows of trap are conformable to the infratrappean beds, but in some instances distinct unconformity has been detected, especially in one case

[1] See Judd: Geol. Mag., Dec. II, Vol. III, p. 343. In several volcanic areas in the neighbourhood of the Alps it is shewn that the volcanic eruptions were preceded by the appearance of springs containing, amongst other substances, silica in solution.

near Jabalpur[1] (Jubbulpore), and it is highly probable that closer examination would shew that such cases are common, and that in many localities where Lametas are wanting, their absence is due to denudation in pre-trappean times. At the same time the denudation appears to have been local, not general, patches occurring here and there, whilst, in the intervals between them, the trap rests upon a formation older than Lameta, but at such an elevation as to shew that the absence of the infratrappean bed is not due to the ground having been above the water in which the Lametas were deposited. It is impossible that the Lametas can ever have been co-extensive with the base of the trap, because the surface on which the latter rests is extremely uneven, and many portions of it must have been above the level at which the infratrappean beds were deposited. To this subject it will be necessary to recur, however, when discussing the relations of the trap series as a whole to the older formations.

Distribution.—It is unnecessary to give a list of localities at which the Lameta group has been observed. It is principally developed in the Central Provinces, around Nágpúr, Jabalpur, &c. It has not been found in the Southern Máhratta country, but elsewhere along the boundary of the volcanic area from the Godávari valley to Bhopal and Indore, it is rarely absent over any considerable area. As a rule, owing to its small vertical development, it only covers small portions of the surface, and it usually forms a narrow fringe to the trap country. In the Western Narbada valley it is replaced by the Bágh group, which, as already shown, it closely resembles in mineral character and stratigraphical relations, and of which it is not improbably a fresh water representative.

Fossils of Lameta group.—The Lameta group is, as a rule, singularly unfossiliferous, the principal fossils which have been found in it consisting of some bones of a large dinosaurian reptile, *Titanosaurus Indicus*,[2] allied to *Pelorosaurus* of the Wealden and *Cetiosaurus* of the Bath oolite. These fossils occur near Jabalpur, and similar bones, together with coprolites and some chelonian remains, are found at Phizdúra (Pisdura) about 8 miles north of Warora in the Chanda district.[3] In the last-named locality some of the characteristic fresh-water mollusca of the intertrappean beds, such as *Physa Prinsepii*, are associated with the bones, and in one or two other localities the same shells have also been found in beds at the base of the trap; for instance, a *Paludina*, apparently identical with *P. Deccanensis*, an intertrappean fossil, was found by

[1] Rec. G. S. I., V, p. 115.
[2] Lydekker: Rec. G S. I., X., p. 38.
[3] Q. J. G. S., 1860, p. 163; Mem. G. S. I., XIII, p. 88.

Mr. Hislop at Nágpúr,[1] *Melania* and *Corbicula* have been met with in infra-trappean beds near Ellichpur in Berar,[2] and *Physa Prinsepii* in a similar position at Todihal, 15 miles north-north-east of Kaladghi in the Southern Máhratta country.[3] But it is by no means clear in those localities, in which fresh-water shells are found in beds beneath the trap, with the exception of Nágpúr, that an intertrappean bed has not overlapped the edge of the underlying lava flow, so as to rest upon an older rock, which may be either Lameta or any other more ancient formation, and in the particular case of Phizdúra, where all the fossils are found scattered on the surface of a field consisting of red Lameta clay, there is always a possibility that *Physa Prinsepii* and similar fossils may come from some small unnoticed intertrappean band, concealed beneath the deep surface soil. At the same time it is by no means improbable that the *Physa* and other shells are really derived at Phizdúra from the Lameta beds, and that this group consequently is not much older than the volcanic beds which overlie it.

The only other noteworthy occurrence of fossils in the Lameta group is that of some fish remains at Dongargaon (Dongargaum) 6 miles east by south, and Dhamni, 9 miles east by north of Warora.[4] The species have not been described, but one of the fish found was considered by Sir P. Egerton allied to the *Sphyrænodus* (a cycloid acanthopterygian) of the London clay.

Intertrappean beds of Nagpur: the Narbada valley, &c.—Leaving the question of the mode of origin of the Lameta group to be discussed hereafter, and deferring for the moment the description of some beds with marine fossils found at the base of the traps near Rájámahendri, the next group which requires notice is that comprising the fresh-water beds interstratified with the lower traps in many parts of India, and especially in parts of the Central Provinces, Northern Hyderabád, Berar and the states north of the Narbada valley. Throughout these tracts of country and beyond them, almost throughout the great trap area, there are found here and there, near the base of the volcanic formations, and in no case, so far as has hitherto been recorded, at a greater height than from 300 to 500 feet above the base, thin bands of chert, limestone, shale or clay, often abounding in fossils of fresh-water or terrestrial origin.

Perhaps the most common form of the intertrappean bands, or that which is most conspicuous, is a compact blackish cherty rock, a kind of Lydian stone. It is clear that this rock has been originally a silt, and has been hardened, either by the outpouring of igneous rock over it

[1] Q. J. G. S., 1860, p. 167.
[2] Mem. G. S. I., VI, p. (283).
[3] Mem. G. S. I., Vol. XII, p. 193.
[4] Q. J. G. S., 1860, p. 162

or by chemical infiltration, the former being the more probable, because it very frequently happens that the upper portion of the bed only is cherty, the lower portion being a soft earthy shale. Other forms of intertrappean bands are a dark or pale grey limestone, often earthy and impure, but rarely gritty, like the characteristic Lameta bed. Not unfrequently the sedimentary bed is composed of volcanic detritus, whether removed by denudation from solid basalt, or consisting merely of the loose products of eruptions, such as lapilli, it is difficult to say. Red and green clays or bole are also found often associated with other intertrappean rocks.

As a rule, the sedimentary beds interstratified with the lava flows are distinguished from those underlying the whole volcanic series by the absence of pebbles and sand, but occasionally, though rarely, sandy and even pebbly beds are found at some distance above the base of the trap. In the Southern Máhratta country most of the intertrappean beds are sandstones and conglomerates. One peculiar detrital form of intertrappean accumulation has hitherto only been described from the country north of the Narbada and south of Chota Udepúr (about 50 miles east of Baroda) on the banks of the Karo, a tributary of the Hiran river.[1] The lower beds of the trap series here consist of conglomerates, sandstones, and sandy grits, sometimes resting on a stratum of basalt, but occasionally on the Bágh cretaceous beds, which underlie the volcanic formations. Occasionally the sandstone or conglomerate appears to be chiefly composed of detritus derived from the metamorphic rocks, but volcanic fragments, usually in the form of rolled pebbles of basalt, can always be found by search, and in many parts the bed becomes a mass of rolled volcanic fragments, often mixed with unrolled scoriæ. At times indeed the rock is a conglomeratic ash, in which rolled fragments of metamorphic rocks and of basalt occur together. Hornblend and pyroxene crystals have been found in these conglomeratic ashy beds, which are in some places as much as 200 feet thick. In some instances the conglomerates appear to have accumulated in hollows, like river beds; but in any case the abundance of rolled pebbles and boulders of trap is important as a proof that denudation took place in the interval between successive lava flows.

With the exception of the detrital accumulations which have just been mentioned, the intertrappean bands rarely exceed a few feet, from 3 to about 20, in thickness, and they frequently do not exceed 6 inches. In many places two or more sedimentary beds occur at different levels in the same section, and the different bands are in some cases dissimilar in mineral character. Thus, at Mekalgandi[2] Ghât in the Sichel hills, south

[1] Mem. G. S. I., VI, p. (327).

[2] Mucklegundy pass of Malcolmson.

of the Pen Ganga river, on the old road from Nágpúr to Hyderabád, a locality famous as being one of the first at which the intertrappean fossils were detected by Malcolmson, the following beds are observed in section :—

1. Trap.
2. Cherty bed containing *Unio*, *Cypris*, &c.
3. Trap.
4. Limestone containing *Cypris* and fragments of small mollusca.
5. Trap.
6. Calcareous grit, containing broken shells (Lameta).
7. Metamorphic rocks.

A single intertrappean bed can but rarely be traced for more than 3 or 4 miles without interruption; it then usually dies out; at the same time it is rare to go over any large tract near the base of the traps without finding some sedimentary bands interstratified, and occasionally one is found to be much more extensive than usual. Thus, an instance is recorded by Mr. J. G. Medlicott[1] in Sohágpur, east of Jabalpur, in which an intertrappean bed was traced for nearly 25 miles.

It would take up too much space to enumerate all the localities at which the lower sedimentary intertrappean beds have been observed. They have been noticed in several places in the Southern Máhratta country; they are commonly found near the base of the trap flows almost throughout the great and irregular line of boundary extending from the Godávari to Rajpútána, and they occur even in small outliers, for instance at Main Pat in Sirguja; they have been detected by Mr. Rogers[2] to the westward at Dohad in the Rewá Kantá, about 75 miles north-east of Baroda, and still farther west in Kachh[3] by Mr. Fedden of the Geological Survey.

Fossils of the lower intertrappeans.—The abundance of fresh water and terrestrial animals and plants in the intertrappean beds has been the principal reason for the comparatively large amount of notice which these thin bands of rock have attracted. The mollusca are very abundant and are occasionally exquisitely preserved in the cherty layers; the commonest species are forms of *Physa* and *Lymnea*, whilst *Unio*, although abundant locally, is of comparatively rare occurrence. *Paludina*, *Valvata* and *Melania* are far from uncommon. Land shells are

[1] Mem. G. S. I., II, p. 201.
[2] Q. J. G. S., 1870, p. 122.
[3] Mem. G. S. I., IX, pp. 58, 240.

very seldom found; but they have been detected[1] in one case at least. Entomostracous crustaceans are very nearly as common as mollusca; all hitherto found belong to the genus *Cypris*. The other remains of animals hitherto detected have consisted of insects, fishes and reptiles, all of which are fragmentary. Plant-remains abound, but leaves are rare, seeds and fragments of wood being more common; and the most abundant vegetable fossils are the seed vessels of *Characeæ*, of which one species has been described under the name of *Chara Malcolmsoni*. The following is a list of the species of animals hitherto described from the intertrappean beds of the Deccan[2] (common or characteristic species are marked with an asterisk, thus *) :—

ARTHROPODA.

INSECTA.

BUPRESTIDÆ.—

Lomatus Hislopi, and three other species imperfectly preserved, but supposed to belong to this family.

CURCULIONIDÆ.—

Meristos Hunteri, and eight species too poorly preserved for description.

CRUSTACEA.

Cypris cylindrica.
C. subglobosa.
Cypris hislopi.
C. hunteri.
Cypris strangulata.

[1] In Mem. G. S. I., II, p. 213, several forms were referred to the terrestrial genus *Achatina*. Some similar fossils from a French deposit had been placed in the same genus, but it appears more probable that the Indian shells are of fresh-water origin and belong to *Lymnea* or to some allied type.

[2] Q. J. G. S., 1860, pp. 154—189, Pls. V—X. The shells were described by Mr. Hislop himself, the insects by Mr. Murray, the *Cypridæ* by Professor Rupert Jones. Some of the shells collected by Malcolmson had previously been described by Sowerby, Trans. Geol. Soc., Ser. 2, V, Pl. XLVII.

The following are figured on Plate XIV of the present work :—

A.—FRESH-WATER.

Fig. 1—2, *Physa prinsepii*.
„ 3, *Paludina normalis*.
„ 4, *P. acicularis*.
„ 5, *P. sankeyi*.
„ 6, *P. deccanensis*.
„ 7, *Valvata multicarinata*.
„ 8, *V. minima*.
„ 9, *Lymnea subulata*.
„ 10, *L. telankhediensis*.
„ 11, *L. spina*.
Fig. 12, *Melania quadrilineata*.
„ 13, *Unio deccanensis*.
„ 14, *U. hunteri*.

B.—ESTUARINE.

Fig. 15, *Pseudoliva elegans*.
„ 16, *Natica stoddardi*.
„ 17, *Cerithium stoddardi*.
„ 18, *Vicarya fusiformis*.
„ 19, *Turritella prælonga*.
„ 20, *Cardita variabilis*.

MOLLUSCA.

* *Melania quadrilineata*, Pl. XIV, fig. 12.	*Bulimus oldhamianus.*
M. hunteri.	*Succinea nagpurensis.*
Paludina normalis, Pl. XIV, fig. 3.	*Lymnea oviformis.*
* *P. deccanensis*, Pl. XIV, fig. 6.	*L. subulata*, Pl. XIV, fig. 9.
P. wapsharei.	*L. attenuata.*
* *P. acicularis*, Pl. XIV, fig. 4.	*L. telankhediensis* var. *peracuminata*, Pl. XIV, fig. 10.
P. pyramis.	*L. telankhediensis* var. *radiolus.*
P. subcylindracea.	* *L. spina.* Pl. XIV, fig. 11.
P. sankeyi, Pl. XIV, fig. 5.	* *Physa prinsepii*, Pl. XIV, fig. 2.
P. takliensis.	Do. var. *elongata*, Pl. XIV, fig. 1.
P. soluta.	Do. var. *inflata.*
P. conoidea.	*Unio malcolmsoni.*
P. rawesi.	*U. deccanensis*, Pl. XIV, fig. 13.
P. virapai.	*U. hunteri*, Pl. XIV, fig. 14.
Valvata minima, Pl. XIV, fig. 8.	*U. mamillatus.*
V. unicarinifera.	*U. imbricatus.*
V. multicarinata, Pl. XIV, fig. 7.	*U. carteri.*
V. decollata.	*Pisidium medlicottianum.*

The plants have not been described, with the exception of the *Chara*. Those collected near Nágpúr are said by Mr. Hislop to comprise about fifty species of fruits and seeds, twelve of leaves and five kinds of woods; the only forms mentioned are endogens and angiospermous exogens. The relations of the fossils will be discussed in the sequel, together with the fauna of the other intertrappean deposits.

The whole of the mollusca and crustacea mentioned are freshwater forms; no marine species have been detected associated with them, except in the beds near Rájámahendri, of which a description will be given in the next paragraph. The insects and plants, with the exception of *Chara*, a fresh-water form, are of terrestrial origin. The general prevalence of the pulmoniferous mollusca *Physa* and *Lymnea* appears to indicate that the water was shallow, as these forms live partly at the surface and are not found in deep water: *Cypris*, too, is commonly found in shallow marshes.

Marine beds associated with trap near Rajamahendri.—The outcrops of trap near Rájámahendri (Rajahmundry) are so remote from any other exposure of the Deccan volcanic series, being about 210 miles distant from the nearest point of the great Deccan area north-west of Sironcha, that some doubt would remain as to the identification, despite the similarity of mineral character, had not some of the typical freshwater fossils of the Deccan intertrappean beds been discovered in the Rájámahendri area. The Rájámahendri outcrops occur on both

banks of the Godávari,[1] and consist of an interrupted narrow band of volcanic rocks, chiefly earthy dolerite and amygdaloid of the usual character, extending altogether for about 35 miles from east-north-east to west south-west. On the left bank of the Godávari, traps are seen at Káteru (Kautairoo of the map) just north of Rájámahendri itself, and extend rather more than 10 miles to the east-north-east, resting upon metamorphic rocks whenever lower beds are seen. On the right bank the volcanic rocks appear in two areas, divided by a small alluvial valley; the larger extends for about 10 miles to the westward from Pangadi, 7 miles west of Rájámahendri; and the smaller occurs a few miles still farther west. In these outcrops the beds of the volcanic series rest upon the jurassic rocks of the Ellore region. In both cases the strata overlying the trap are tertiary sandstones (Cuddalore group), and all the beds alike have a low dip to south or south-east. The whole thickness of the volcanic series at this locality, as already mentioned, nowhere appears to exceed about 200 feet, and in places it is not more than 100.

Infratrappean.—At the base of the traps and intervening between the basalt flows and the underlying jurassic sandstone, near the village of Dúdúkúr, twelve miles west of Rájámahendri, about 50 feet of sandstone, white, yellowish or greenish in colour, is exposed. The upper portion is calcareous, and, on the top, there is a band about 6 inches to 2 feet thick of sandy limestone abounding in marine fossils, the most abundant of which is a *Turritella* apparently identical with *T. dispassa* of the cretaceous Arialúr group. If not identical, the two species are very closely allied. A *Nautilus*, about fifteen *Gasteropoda* and eleven *Lamellibranchiata* accompany the *Turritella*, but not a single species, except *Turritella dispassa*, has been recognised as identical either with the cretaceous beds of Southern India or with the eocene fossils of the nummulitic group. The collections have not, however, been sufficiently compared to enable the species to be determined with certainty. Only one single species, too, *Cardita variabilis*, has been recognised as occurring also in the overlying intertrappean bed. Although the whole facies is tertiary, there is a remarkable absence of characteristic genera,[2] and the chief distinction from the cretaceous fauna

[1] The account of these beds is chiefly from manuscript reports by Mr. King. The intertrappean beds were discovered originally by General Cullen and Dr. Benza, and collections of the fossils were made by Lieutenant Stoddart and Sir W. Elliot, and described by Mr. Hislop (Q. J. G. S., 1860, pp. 161, 176, &c.) The infratrappean band was first noticed by Mr. King, (Rec. G. S. I., VII, p. 159).

[2] Amongst the genera identified are *Rostellaria*, several forms of *Muricidæ*, *Volutilithes* near the tertiary *V. torulosa*, *Natica*, *Turritella*, *Dentalium*, *Cytherea* or allied genera (three sp.), *Cardita* (four sp.), *Corbis*, *Pectunculus*, *Cucullæa* and *Ostrea*.

of the upper beds in Southern India is simply the want of any marked cretaceous form. The fauna is distinctly marine.

It is difficult to say whether this bed should be referred to the Lameta group or not. The mineral character is similar, but all known Lameta outcrops are so distant that the identification is somewhat doubtful. The distinctions between the fossils of the Bágh beds and those of the infratrappeans of Dúdúkúr and Pangadi appear too great to be attributed solely to the existence of a land barrier between the two areas; it is difficult to suppose that the two formations can be of the same geological age, and the difficulty consequently arises that, if the Lameta beds represent the Bágh group, they are probably more ancient than the Pangadi infratrappeans. Still the balance of evidence is rather in favour of referring the latter to cretaceous times than to tertiary. They may be of intermediate age.

Intertrappean beds of Rajamahendri.—Upon the fossiliferous limestone described in the last paragraphs a flow of basalt is superposed, varying in thickness from about 30 to about 100 feet. There is an appearance of slight unconformity where the volcanic rock rests upon the sedimentary bed, the surface of the latter being slightly uneven, as if denuded, and the upper fossiliferous infratrappean zone is occasionally wanting. The variation in thickness of the basalt stratum may be due to its having been poured out upon an uneven surface, but it is not quite clear whether this unevenness was due to disturbance of the sedimentary beds before the outburst of the traps. That the denudation of the underlying formations can have been only partial is shewn by the fact that they may be traced between 3 and 4 miles, the upper portion alone being locally absent.

On the left bank of the Godávari near Rájámahendri itself, the infratrappean band has not been observed. The thickness of the lower flow of basalt cannot be clearly ascertained, but it is not less than 40 or 50 feet, and it is probably more. Above this lower flow on both banks of the Godávari, there is found a sedimentary band, 12 to 14 feet thick at Káteru, where it only extends for about half a mile, and about 2 to 4 feet thick in the Pangadi direction, where it has been traced for about 10 miles. The intertrappean bed consists of limestone and marl, and portions abound in fossils. Numerous quarries which have been opened near both Pangadi and Káteru have afforded good opportunities for obtaining fossils, which are difficult to extract from the argillaceous limestone when it is first quarried, but weather out on exposure. About 30 or 40 feet above the fossiliferous limestone of Káteru, another sedimentary bed, consisting of yellow calcareous shale, is seen in one place. It is very thin, and no fossils have been found in it.

Fossils of Rajamahendri intertrappeans.—The following is a list of the species of mollusca described by Mr. Hislop from the Rájámahendri intertrappean beds :—

GASTEROPODA.

Fusus pygmæus.	*Turritella prælonga*, Pl. XIV, fig. 19.
Pseudoliva elegans, Pl. XIV, fig. 15.	*Paludina normalis*, Pl. XIV, fig. 3.
Natica stoddardi, Pl. XIV, fig. 16.	*Hydrobia ellioti.*
Cerithium multiforme.	*H. carteri.*
C. subcylindraceum.	*H. bradleyi.*
C. leithi.	*Hemitoma multiradiata.*
C. stoddardi, Pl. XIV, fig. 17.	*Physa prinsepii*, Pl. XIV, figs. 1, 2.
Vicarya fusiformis, Pl. XIV, fig. 18.	*Lymnea subulata*,[1] Pl. XIV, fig. 9.

LAMELLIBRANCHIATA.

Corbula sulcifera.	*Cardita pusilla.*
C. oldhami.	*Corbicula ingens.*
Psammobia jonesi.	*Corbis elliptica.*
Tellina woodwardi.	*Lucina parva.*
Cytherea orbicularis.	*L. (Kellia) nana.*
C. wilsoni.	*Nucula pusilla.*
C. wapsharei.	*Arca striatula.*
C. rawesi.	*Modiola*, sp.
C. jerdoni.	*Perna meleagrinoides.*
C. elliptica.	*Lima*, sp.
C. hunteri.	*Anomia kateruensis.*
Cardita variabilis, Pl. XIV, fig. 20.	*Ostrea pangadiensis.*

The most marked feature of this fauna is its distinctly estuarine character. *Cerithium multiforme* appears to be a *Tympanotonus* or *Pirenella*. *C. leithi* has the characteristic form and sculpture of a *Cerithidea*, and *C. stoddardi* is, at least, as much allied to *Potamides* as to *Cerithium* proper. *Tympanotonus, Pirenella, Cerithidea* and *Potamides* are all brackish water forms. *Hydrobia* is an estuarine genus, and the fossil called *Hemitoma* closely resembles a species of *Acmæa* found living in creeks in the deltas of Indian rivers. Some of the shells referred to *Cytherea* agree best with the typical forms of the genus (*Meretrix*), many species of which abound in backwaters and at the mouths of rivers, and Mr. Hislop has remarked the similarity between *Corbula oldhami* and a Brazilian species belonging to the estuarine genus *Azara*. There is a complete absence of pelagic shells such as the *Cephalopoda*, no *Echinodermata* or corals are found, and above all, four species are characteristically fresh-water forms, *viz.*, *Physa prinsepii, Lymnea subulata, Paludina normalis* and *Corbicula ingens*. It is true that the three first are of comparatively rare occurrence, whilst the *Corbicula* is common, and perhaps the last named may have lived in brackish water, as its near ally *Cyrena* does at the present day, whilst

[1] Not included in Mr. Hislop's collections, but obtained since from Kateru.

the purely fresh-water shells were washed down by rivers; but this view is quite in accordance with the theory that the intertrappean beds of Rájámahendri were deposited in brackish water, which was supplied with fresh water by streams, but which was also in communication with the sea.

The mollusca, however, cannot be considered as very characteristic of age. They were compared by Mr. Hislop with the nummulitic fauna of Western India; but, as he points out, no forms appear to be identical, and although *Natica dolium*, *Turritella affinis* and an unnamed *Cerithium* found in the tertiaries of Sind and Cutch, resemble *N. stoddardi*, *T. prælonga* and *C. stoddardi*, the intertrappean forms are more closely allied to the cretaceous *N.* (*Mammilla*) *carnatica*, *T. elicita* and *Cerithium vagans* than to the eocene species mentioned,[1] and other forms might easily be shewn to be affined to those occurring in the cretaceous rocks of Southern India. In the case of *Turritella prælonga* and *T. elicita* the affinity is very great. The shell called *Vicarya fusiformis* appears not to be really congeneric with *V. verneuilli*, the type of the genus,[2] and the latter has now been found to be miocene, not eocene. On the whole, it may be safely asserted that no tertiary alliances of any value have been detected amongst the intertrappean Rájámahendri fossils, and that their relations are rather with the upper cretaceous rocks of Southern India, although the connexion is not strong.

Upper intertrappean beds of Bombay[3].—In the Islands of Bombay and Salsette, and probably farther north on the same line of coast, the trap rocks have an inclination of from 5° to 10° to the westward. The islands are separated from each other and from the mainland to the north by tidal creeks and alluvial flats, whilst between them and the mainland to the eastward is the expanse of water forming Bombay Harbour. In the islands of the harbour, and on the hills between Tanna and Kalyán north of the harbour, the same westwardly dip is displayed, whilst farther to the eastward from Kalyán to the Sahyádri range the traps are horizontal.

[1] When Mr. Hislop wrote, the South Indian cretaceous fossils had not been described.

[2] This was pointed out by Mr. H. M. Jenkins, Q. J. G. S., 1864, p. 58. He also, p. 65, suggested that the Sind beds containing *Vicarya* were newer than eocene, a view since confirmed.

[3] For fuller descriptions of these beds, see Carter, Jour. Bombay Br. Roy. As. Soc., IV, p. 161, and "Geological Papers on Western India," p. 128. It must not be forgotten that Dr. Carter's views as to the relations of the sedimentary beds differ essentially from those stated in the text, with which all other observers agree. See also Buist; Trans. Bombay Geogr. Soc, X, p. 195, and Wynne, Mem. G. S. I., V, p. (193), and VI, p. (385). Besides Drs. Carter and Buist, Dr. Leith and Mr. G. T. Clark have added greatly to our knowledge of the geology of Bombay Island.

About 2,000 feet of horizontal beds are exposed on the flanks of Matherán hill, and a still greater thickness farther to the east in the hills near the Bor Ghât and close to the Great Indian Peninsula Railway line between Bombay and Poona; but as no lower beds than the traps are seen, it is impossible to say how far the lowest strata exposed at the base of the hills are above the bottom of the series. Without closer measurements than have hitherto been made, it is difficult, owing to the numerous breaks in the section, to estimate the precise thickness of the rocks dipping to the westward near Bombay, but taking the average dip at 5°, the whole thickness turned up in 15 miles would be nearly 7,000 feet.[1] This is a minimum estimate; probably the average dip is higher, and the thickness consequently greater. From 1,200 to 1,500 feet of rock are exposed in Bombay Island, so that it is evident that the lowest beds seen on the island are higher in the series than the highest flows seen on the Sahyádri mountains to the eastward, even although some of the higher portions of the range are 4,000 feet above the sea.

The intertrappeans of Bombay are entirely confined, so far as is known, to these higher beds, no sedimentary rocks having hitherto been found amongst the middle portions of the Deccan trap series. It is manifest that the Bombay fresh-water beds belong to a very different horizon from that to which the intertrappeans of Nágpur and the Narbada valley must be assigned. The most important bed is that which underlies the basalt of Malabar hill and Worlee hill, forming the broken ridge along the western or sea face of the island; consequently this stratum is immediately beneath the highest lava flow known to occur anywhere throughout the trap area, for the rocks, as already stated, dip to the west, and no beds higher than those of Bombay have been discovered. It must, however, not be forgotten that the coast north and south of Bombay has not hitherto been examined with sufficient care to make it quite certain that no higher beds occur.

This intertrappean bed on the east side of Malabar hill is in places more than 100 feet thick, and consists principally of soft grey, greyish-blue, brown, and brownish yellow earthy shales, with occasional harder bands, some of which are black and carbonaceous. The greater portion of the bed is evidently formed of volcanic detritus, whether lapilli washed down by water, or sand produced by the disintegration of lava flows, it is difficult to say; very possibly both may have contributed to the formation of the rock. Occasionally, at the top of the deposit, the shale becomes hardened and silicious, as if by the action of the overlying

[1] This appears more probable than the much lower estimate of 4,000 or 5,000 feet given in Mem. G. S. I., VI, p. (151).

basalt. The black carbonaceous shale is locally highly bituminous and sometimes contains small layers of a coaly substance and fragments of mineral resin. Impressions of vegetables abound, although they are but seldom well preserved, and remains of animals are common, the best known being skeletons of small frogs and carapaces of *Cyprides*.

Besides this thick sedimentary band, several thinner beds have been found at lower horizons amongst the lava flows and ash beds of Bombay Island. They are, however, very thin, and except one, which is seen in the quarries of Nowroji hill, south of Mazagaon, they are difficult to detect; indeed, the circumstance of their occurrence has only become known through the careful scrutiny of local geologists, who, living in the town, could take advantage of any excavations for buildings, tanks, roads, &c., to examine the strata exposed. According to Dr. Buist there are five or six sedimentary beds below the thick band of Malabar hill, &c., but fossils have only been found in that exposed at Nowroji hill, where *Cyprides* occur. All these bands consist of shaly beds.

Fossils of Bombay intertrappean beds.—The fossils found at Bombay are tolerably numerous, but hitherto only the *Vertebrata* appear to have received more than a superficial notice. The remains of a fresh water tortoise, *Hydraspis leithi* (*Testudo leithi*, Carter) belonging to the *Emydidæ*, and of a frog, *Rana pusilla*,[1] considered by Dr. Stoliczka an *Oxyglossus*,[2] have been found, the latter in abundance, whilst some bones of a larger frog have been obtained. The *Arthropoda* are represented by three species of *Cypris*, one of which, *C. cylindrica*, is also found in the intertrappean deposits of the Deccan; another species has been called *C. semimarginata* by Dr. Carter, the third is unnamed. *C. semimarginata* is the most generally diffused, but the other forms also occur in great numbers. Only fragments of insects have been found. Mollusca are rare, and the few specimens hitherto procured have been in poor condition; they have been referred to *Melania* and *Pupa*, but with some doubt, and none of the characteristic Deccan forms have been detected. The plant-remains comprise stems, leaves, seeds, and perhaps roots, but very little has been determined, except that endogens and angiospermous exogens are represented.

The life represented by the species named is clearly that of a shallow marsh. The frogs occur in large numbers, and their bodies have evidently been deposited near the spot where they died, as the whole skeleton

[1] Owen: Q. J. G. S., 1847, p. 224.

[2] Mem. G. S. I., VI, p. (387). Dr. Stoliczka shews that the form agrees well with *Oxyglossus* and with no other known existing genus. At the same time, as some of the principal characters by which genera of frogs are distinguished are not preserved in the skeleton, the Bombay frog may have differed greatly from recent *Oxyglossi*. From the species of true *Rana* it is distinguished by the want of vomerine teeth, the large head, and short hinder limbs.

is found perfect; in some cases, as was noticed by Dr. Stoliczka,[1] the skeleton has been dragged along the surface of the shale in which it is embedded, and he suggests with great probability that this was done by wind. The tortoise is a marsh or river form, the nearest living ally, according to Dr. Gray,[2] being a genus found in fresh water in South America.

Origin of the Deccan traps sub-aerial.—After the description of the various sedimentary formations intercalated with the traps or underlying them, the next point for consideration is the mode of origin of the trap rocks themselves. Their volcanic character is sufficiently proved by their composition; precisely similar rocks occur amongst the lavas poured out from recent volcanoes, whilst nothing of the same kind has ever been known to be deposited from water. But the first difficulty which arises, and it is one of very great importance, is to account for the persistent horizontality of the beds. Two observers certainly, Jacquemont[3] and Adolph Schlagintweit[4] have considered that the traps are unstratified, but after the evidence already mentioned as to the differences in mineral character between successive bands, the frequent occurrence of vesicular structure on the upper surface of flows, the presence in abundance of beds of volcanic ash, and the repeated interstratification in the same localities of sedimentary layers, it is unnecessary to refute this view. A much more common opinion, and one which has been supported by numerous excellent geologists, from Newbold downwards, is that the Deccan traps are of subaqueous origin, and it is necessary to shew why this opinion is untenable.

In all cases of subaqueous eruptions, the ejected masses consist of substances very similar to the lava, ashes, scoriæ and lapilli of ordinary subaërial volcanic outbursts, but these materials being thrown out into the water are reduced by the sudden cooling to the condition of a fine powder, which is dispersed and deposited in layers in the same manner as ordinary detritus, so as to form what are known as stratified tuffs.[5]

[1] Mem. G. S. I., VI, p. (393).

[2] Ann. Mag. Nat. Hist., Ser. 4, VIII, p. 339.

[3] "Voyage dans l' Inde," Vol. III, pp. 594-596, &c.

[4] "Report of the Proceedings of the Officers engaged in the Magnetic Survey of India," No. I, p. 6. Reisen in Indien und Hochasien, I, p. 141.

[5] "The volcanic products thus forced out under the sea present, as might be expected, a very different aspect from that of the ashes, scoriæ, and lava from terrestrial volcanoes; the molten lava, coming in contact with the water, is at once broken up into fragments, coarser or finer in proportion to the greater or less cooling power of the water in immediate contact with them, and often in great part instantly converted into fine mud, of a greyish colour when formed from trachytic lava, but more commonly of chocolate or other dark tint, and much denser when produced from the ordinary pyroxenic lava. Beds of this character spread out by the action of the sea, often enclosing shells, fish and other organic remains, become in time consolidated and upheaved, and as they often present an appearance much resembling ordinary volcanic rocks, they have frequently puzzled geologists, who at first found a difficulty in explaining the presence of such fossils in rocks apparently of igneous origin."—D. Forbes: Geol. Mag., 1870, p. 323.

With these tuffs ordinary marine deposits are necessarily intercalated, and both these and the tuffs are usually fossiliferous, the very destruction of life in the waters of the sea, caused by the heat and gases which are evolved during eruptions, ensuring the preservation of those portions of the organism which are not liable to destruction from the temperature of boiling water or the process of decomposition. Now, the volcanic ashes already described as occurring in great abundance amongst the higher beds of the Deccan traps are not, as a rule, stratified in the manner in which beds deposited from water would be. Although they occur in strata intercalated with basaltic lava flows, these ash beds themselves have no internal lamination, except in a few rare instances, in which they are chiefly composed of bole, and may have been formed in the small pools of fresh water so common in volcanic areas. Above all, not a trace of a marine organism has ever been found in any ash bed, or in any rock intercalated with the traps, except in the inter-trappean and infratrappean formations of Rájámahendri, in which case the lava has evidently been poured out on the coast, the intertrappean beds, as already shewn, being estuarine, and the infratrappean littoral It may be thought that the prevalence of volcanic conditions would destroy all life in the sea, and thus the absence of marine fossils in the traps may be explained, but even if this view were conceded, (and it is entirely opposed to all that is known of recent submarine volcanic action,) there must have been a great destruction of life at the commencement of the volcanic epoch, and some traces of the animals destroyed would have been preserved.

Relation of Deccan traps to underlying rocks.—The evidence afforded by the characters of the traps and the absence of marine fossils is, therefore, opposed to the hypothesis of a submarine origin, and the relations of the lowest lava flows to the underlying rocks are strongly antagonistic to the idea that the volcanic outbursts were subaqueous. The surface of the older rocks upon which the traps rest is in many parts extremely uneven, the basalt filling great valleys, sometimes as much as 1,000 feet in depth, the form of which shews that they were excavated by subaërial erosion. Admirable examples are seen between Bhopal and Hoshangabád, where the Deccan traps rest upon an extremely uneven surface of Vindhyan rocks.[1] It is true that this uneven surface might have been formed above the sea and then depressed beneath the water, but as periods of depression are always favourable for the accumulation of sediment, we should in this case expect to find aqueous deposits of considerable thickness at the base of the volcanic rocks. It is remarkable

[1] Mem. G. S. I., VI, pp. (240), (242), &c.

that precisely in this uneven ground no deposits whatever are found at the base of the traps, and the general absence of any infratrappean deposit has been noticed in the Southern Maratha country, where also the surface upon which the traps rest is very irregular.

Where the underlying formation consists of the cretaceous Bágh beds, these are, as a rule, conformable to the volcanic series, and it might be thought that in this tract of country the traps were submarine. But every here and there, a spot is found where the cretaceous rocks are wanting, and where the level of the infratrappean surface shews that their absence is due to denudation.[1] In some cases where the Bágh beds are not more than 30 or 40 feet thick, the denudation which has removed them has only extended over a small area, and has scarcely affected the harder rocks beneath, and from the small area, often only a few yards wide, over which the cretaceous rocks have been removed, it is evident that the denuding agent was subaërial erosion. It has also been ascertained that the Bágh beds had been locally disturbed to a small extent, besides having suffered from denudation, before the commencement of the volcanic outbursts. As has already been noticed in the description of the Lameta beds, their relations to the lowest traps are precisely similar to those exhibited by the marine cretaceous beds of the Western Narbada valley; there is the same slight disturbance and local denudation, although, as a rule, the two formations are conformable.

Subaërial origin proved by fresh-water beds.—Lastly, the circumstance that, with the single exception of the estuarine intertrappean band of Rájámahendri, every fossiliferous sedimentary bed intercalated with the Deccan traps is unmistakably of fresh-water origin, is a conclusive proof that all those lava flows which are associated with such sedimentary beds are not submarine. We have thus not only a complete absence of all proof of submarine origin,[2] but clear and unmistakable evidence that the traps were in great part of subaërial formation.

Lower traps not poured out in a great lake.—Another favourite idea with many writers, and especially with Mr. Hislop and Dr. Carter,

[1] Mem. G. S. I., VI, pp. (212), (300), (313), &c.

[2] It may appear to many geologists that an unnecessary amount of space and argument has been devoted to proving a very clear proposition, *viz.*, that the Deccan traps are subaërial. The reason for giving the arguments at length is that a different view has been expressed by many geologists, and repeated within the last few years in the "Memoirs of the Geological Survey of India," Vol. IX, p. 60, &c. A reference to the "Quarterly Journal of the Geological Society of London," Vol. XXX, p. 225, will shew that the arguments used by Professor Judd, to prove the subaërial origin of the volcanic rocks in the west of Scotland and north of Ireland, are precisely the same in many cases as those mentioned above. These views had been urged in the case of the Indian rocks (Mem. G. S. I., VI, p. (145), some years before the publication of Professor Judd's papers.

has been that the lower traps were poured out in a vast, but shallow, fresh-water lake extending throughout the area over which the "inter-trappean limestone formation" extends.[1] This hypothesis involves the existence of a lake of enormous size, several hundreds of miles in length and breadth, but shallow throughout. It appears more probable that the lakes in which the Lameta group and the intertrappean beds were deposited were of moderate size, and that they were formed by unequal elevation of different parts of the area prior to the volcanic outbursts, or by the obstruction of the drainage of the country by lava flows. The lake or lakes in which the Lameta beds were formed may have been more extensive, but it has already been shewn that single sedimentary bands intercalated in the traps, can rarely be traced for more than three or four miles, and the character of the fauna, in both the groups of intertrappean formations,—those of Central India and those of Bombay,—is in favour of the animals of which the remains are found having inhabited shallow marshes rather than deep lakes.

Horizontal traps difficult to explain.—We are thus thrown back upon our original difficulty, the horizontality of the Deccan traps. It has been shewn that this is not due to a subaqueous origin, whether marine or fresh-water. At the same time the phenomenon cannot be said to have been thoroughly explained, because no such formation is known to be in process of accumulation at the present day. Many such masses of horizontal stratified traps are, however, found in various parts of the world, and although it is impossible for want of recent examples to demonstrate the circumstances which cause their formation in place of volcanic cones, there is abundant evidence that such traps were in past times a common form of volcanic accumulation, and moreover that

[1] By both the writers named the intertrappean beds of Bombay were supposed to be identical with those of Central India, and both were under the impression that there was but a solitary fresh-water bed which was deposited before any volcanic outbursts took place, which was then covered up by lava flows, and finally separated from the underlying rocks, and broken up by a great sheet of intrusive basalt injected beneath it.

The geologists named would doubtless have modified their views had they been acquainted with all the facts now ascertained with regard to the Deccan traps and the associated sedimentary beds. The conception of a great sheet of intrusive basalt so injected between two formations that it always overlies the one and underlies the other, over an area of thousands of square miles, is quite untenable. It is a physical impossibility that an immense dyke should be injected for hundreds of miles instead of breaking through to the surface. Moreover, the fact that successive sedimentary beds, as in the case at Mekalgandi Ghát, mentioned on page 313, are often of different mineral composition, and the very frequent instances in which the upper surface of a sedimentary band is altered, whilst the lower is unchanged, prove that both lava flows and sedimentary "intertrappean" beds were regularly and successively formed, one above the other, as they now occur.

similar stratified lava flows were not confined to any particular epoch, although several instances are known of about the same geological age as that attributed to the Deccan outbursts.

Volcanic foci.—Assuming therefore, as we are justified in doing, that the horizontal dolerites of Western and Central India precisely resemble modern lavas in everything except their horizontality and the extent of area which they have covered, it remains to be seen what evidence there is of the sources from which this enormous accumulation of molten materials was poured out. The original cones and craters, if any ever existed, must have been the first portion of the volcanic area to suffer from denudation, and it is easy to conceive that subaërial erosion, from eocene times to the present, would have more than sufficed to remove every trace of the loose material of which volcanoes are chiefly composed. Still it is surprising that the inclined beds forming the slopes of a volcanic cone should in no single case have been recognized as having been preserved by being encased in subsequent outbursts of harder materials. Possibly the tendency of great lava streams to sweep away all loose volcanic materials, may suffice, in those cases in which large quantities of lava are poured out, to prevent volcanic cones from forming.

When, however, we look for other evidence of the neighbourhood of igneous outbursts, we find dykes and irregular intrusions abundant in some localities, rare or absent in others, whilst the presence of volcanic ash throughout a large portion of the trap area has already been noticed. The ash-beds, especially when, as usually happens, they form a coarse volcanic breccia, containing blocks several inches in diameter, cannot have accumulated far from volcanic vents, although they may have been transported to a much greater distance floating on the surface of molten lava, than they could have been ejected from the volcano.

A much closer examination of the Deccan area than has hitherto been practicable will be requisite before the distribution of dykes and ash beds can be considered as even approximately known. So far as the country has hitherto been examined, both appear to prevail much more largely in the region near the coast, from Mahableshwar to the neighbourhood of Baroda, than in other parts of the trap area. It is, of course, very often difficult to recognise dykes amongst rocks of precisely similar mineral character, much closer search being needed than is requisite in order to detect volcanic intrusions amongst sedimentary formations. It is only where dykes are large and numerous that attention is likely to be directed to them.

There is one tract of country in which dykes are peculiarly large and abundant. This is in the Rájpipla hills, north-west of Surat. In this

country, over a considerable area, very large parallel or nearly parallel basalt dykes are found, sometimes not more than 200 or 300 yards apart, the general direction being east by north to west by south. The traps are much disturbed, and frequently dip at considerable angles.

To the southward of the Tapti, along the line of the Sahyádri, and its neighbourhood, in Western Khandesh, the Northern Konkan, and the small intermediate native States, a tract of which the geology is unknown, it is probable that dykes may continue numerous for a considerable distance, as their number and size in the Konkan, north-east of Bombay, are especially noticed by Mr. G. T Clark,[1] but intrusions are far from abundant in the lava flows exposed in the higher country east of the Gháts, although a few occur. At the same time the frequent occurrence of ash beds in the higher traps around Poona and Mahableshwar sufficiently attests the neighbourhood of the old volcanic vents.[2]

North of the Rájpipla hills and of the river Narbada, and west of Baroda, trap dykes are not so common as in the Rájpipla hills, but intrusive masses occur; one of these, forming Matapenai or Kurali hill, about 14 miles south-west of Chota Udepúr, is a mass of grey trachyte or trachy-dolerite, containing enormous masses of granite, evidently derived from the metamorphic rocks through which the mass, when molten, passed on its way to the surface. The siliceous character of the intrusion in this and some other cases is perhaps due to the fusion of quartzose metamorphic rock in the basic dolerite. Another trachytic core was noticed near the village of Pudwani, 18 miles west of Broach. The occurrence of fragments derived from the metamorphic rocks in intrusive dykes is by no means an uncommon occurrence.

It is only natural that far better evidence of volcanic foci is to be found outside the trap area, or in the inliers of older sedimentary rocks exposed within the main boundary, than amongst the lava flows themselves, and it may therefore be useful to point out very briefly the distribution of such intrusive masses so far as the country is known. Commencing to

[1] Q. J. G. S., XXV, p. 164.

[2] Mr. Clark, *loc. cit.*, states that a series of such vents running north and south actually exists in the Konkan. The only reasons for doubting whether his views are quite accurate are that he repeatedly writes of vents, whilst the present cores of the old foci usually stand out as hills, that he apparently looks upon the western dip of the Bombay traps as their original slope, although the inclination of the interstratified sedimentary beds shews that the dip is due to subsequent disturbance, and that he does not appear to be aware that the scarps of the gháts are due to denudation, and that consequently an immense thickness of beds has been removed from above the surface of the Konkan. His observations on the dykes are excellent and evidently trustworthy.

the north-west, no trap dykes have been found in Sind, where, however, the deposits of older date than eocene cover an exceedingly small area. In Cutch, however, throughout the jurassic rocks, intrusive masses of basalt and dykes of large size abound, and some of the former rise into hills of considerable size.[1] Kattywar has been but little explored, and the abundance of intrusive trap in the lower Narbada valley has already been mentioned. Throughout the northern edge of the trap country in Rajpútána, Gwalior and Bundelkhand, dykes are rare or wanting, but they abound in some of the areas of older rocks exposed in the Narbada valley, and they are especially common in the Gondwána tract, south of the river, in the neighbourhood of the Mahádeva hills. Farther to the eastward they are less numerous, but some occur throughout the upper Son valley, and they gradually die out in Sirgúja and Palamaun (Palamow) only 200 miles west of the ground in which the older lava flows of Rájmahál age are seen, and within less than 100 miles of the Gondwána basins in the upper Damuda valley, which are traversed by basalt dykes probably of the same age as the Rájmahál traps. Passing southwards from Jabalpur and Mandla, however, there is a total absence of volcanic intrusions amongst the Vindhyan and Gondwána formations of Nágpúr and Chánda, and none have as yet been noticed in the neighbourhood of the Pránhita and Godávari between Chánda and Rájámahendri. The country south of the Godávari and north-west of Hyderabád is still imperfectly known, but in the South Máhratta country, and the Konkan near Vingorla, the few dykes which have been observed traversing the unmetamorphosed azoic strata are but doubtfully connected with the Deccan traps. Ashes, moreover, are much less abundant in this region, amongst the Deccan flows, than they are further north.

We have thus abundance of evidence of the former existence of volcanic foci in Cutch, the Rájpipla hills and the lower Narbada valley and probably in the neighbourhood of the Sahyádri range east and north-north-east of Bombay, whilst there is every probability that vents extended to the eastward as far as South Rewah and Sirgúja; but there is no evidence of any having existed in the Nágpúr country or to the south-east. Yet, as the traps are found represented at Rájámahendri, it appears probable that they once extended over all the Godávari valley. Still, it is quite possible that the Rájámahendri outlier may have been

[1] One of these, called Denodhar, was described originally as a volcano. Trans. G. S., Ser. II, Vol. V, p. 315, and the statement that it is an extinct crater has been repeated in numerous geological works. The hill is very probably the basaltic core of an old volcano, but its date is anterior to that of the nummulitic formation. Its crateriform appearance is due to denudation.

originally isolated and derived from a centre which has not been discovered.

It is, however, very clear that the lava flows must have extended to an enormous distance from the vents through which the molten material was poured out. The neighbourhood of Nágpúr and Chánda have been examined so closely that the improbability of any intrusions of igneous rock having been overlooked is much greater than in most parts of the country. Trap-dykes are rarely solitary; they are, as a rule, abundant in the neighbourhood of volcanic foci. It is known that the comparatively moderate outbursts from existing volcanoes flow to great distances from their source. The excessive fluidity of the Deccan traps is proved by their horizontality, for they must have been poured out in immense sheets of but slight thickness, but of great horizontal extension, and it is difficult to form an accurate idea of the distances to which they may have flowed before consolidating. Further observations are necessary before all the sources of the great volcanic series of Western India can be said to have been even approximately determined.

Geological age of the Deccan traps.—The question of the geological age to be assigned to the Deccan volcanic outbursts has been left to the last, because it was desirable to precede it by a full statement of all the facts upon which a conclusion may be founded. The evidence to be recapitulated is twofold, that founded on the affinities of the fossils found in the various intertrappean rocks, and that derived from the relations of the stratified traps to beds above and below them. It is, of course, clear that the traps rest upon cretaceous beds and are overlaid by nummulitics, and the only question is whether the lava flows are cretaceous or eocene.

The most important clue to the correlation of the volcanic rocks with the known series of fossiliferous deposits might be expected to be obtained from the marine beds associated with the volcanic formations at Rájámahendri. This, however, as has been already shewn in the description of the sedimentary beds, proves of little service. So far as is hitherto known, the relations of both the infratrappean and intertrappean faunas are with the cretaceous rather than with the tertiary beds, but the points of connexion, in the latter case especially, are quite insufficient to decide the affinity of the formations.

Turning to the fresh-water fauna of the intertrappean beds, the first difficulty is, of course, the same as in the case of the Gondwánas, the question arises what dependence is to be placed upon terrestrial animals and plants as a guide to geological age. In the case of the Gondwána formations it has been shewn that forms characteristic of particular epochs

in Europe occur in a very different position in the geological sequence in India, and it is, therefore, necessary to be cautious in accepting conclusions founded upon slight evidence. There is a very marked similarity between some of the fresh-water mollusca of the Deccan intertrappeans and species found in some beds of plastic clay age (lower eocene) occurring at Rilly-la-Montaigne in Northern France[1] one species of *Physa*, *P. gigantea*, from the latter locality being considered by some palæontologists identical with the Indian *P. prinsepii*. This identification is, however, to say the least, extremely doubtful, and the fauna of the Rilly beds appears more recent than that of the Deccan intertrappeans. Other resemblances between the plants and fish of the intertrappean beds and those of the London clay have also been indicated, and a *Physa*, said to be allied to *P. prinsepii*, has been found in the nummulitic rocks of the Himalayas, but even the generic identification in the latter case is far from certain.[2] This evidence only suffices at the most to shew an approximation between the age of the Deccan trap and the lower eocene, and is quite insufficient to prove whether the former should be classed as uppermost secondary or lowest tertiary. On the other hand, the very probable connexion already shewn to exist between the Lameta group and the Bágh beds on the one hand, and the occurrence in the Lametas of intertrappean fossils on the other, furnish a connecting link between the lower traps and rocks of middle cretaceous age.

The relations between the traps and the underlying cretaceous beds of the lower Narbada valley have been already described. There is general conformity, with local unconformity, due to slight and apparently subaërial denudation of the underlying beds. In a very few localities also the latter appear to have been disturbed before the formation of the lowest traps. Between the highest volcanic beds and the nummulitic rocks of Surat and Broach, the break appears to be much greater, not only do the tertiary rocks rest upon a largely denuded surface of the traps, but they are in a great measure composed of materials derived from the disintegration of the lava flows, the lowest tertiary beds being frequently coarse conglomerates of rolled basalt fragments, whilst beds, hundreds of feet in thickness, are chiefly composed of agates derived from the traps. This, however, although it proves that great denudation of the volcanic rocks took place during the deposition of

[1] Mem. Soc. Geol. de France, Ser. II, Vol. III, p. 265. The genera found at Rilly-la-Montaigne, are *Cyclas*, *Ancylus*, *Vitrina*, *Helix*, *Pupa*, *Clausilia*, *Megaspira*, *Bulimus*, *Achatina*, *Auricula*, *Cyclostoma*, *Paludina*, *Physa*, *Valvata*. The majority of these genera are terrestrial forms.

[2] D'Archiac and Haime : Desc. An. Foss. Num. de l'Inde, p. 277.

the nummulitic formations, does not necessarily imply a great break and an interval of disturbance prior to the commencement of the tertiary epoch, because the traps, being of subaërial origin, were, unlike most sedimentary rocks, subject to erosion from the period of their formation. The unconformity at the base of the traps, however, is distinctly marked, and appears to shew a great break in the sequence. The lowest tertiary beds near Surat contain fossils which appear to be a mixture of middle and lower eocene forms (Khirthar and Ranikot).[1]

Farther to the westward, in Cutch, the rocks at the base of the tertiary group resting upon the trap are locally conformable, and they have even been considered[2] to be partially volcanic, but, as will be shewn in the next chapter, there can be no doubt that a break, marked by unconformity, exists between the two series. It appears most probable, too, that the lowest tertiary beds are really composed of detritus derived from the volcanic rocks, as all appear to be of sedimentary origin, and no instance has been noticed of intercalation with the lava flows. The great difficulty of distinguishing between volcanic ash and the detritus of igneous rocks when mixed with ordinary sediments, especially where, as in Cutch, the rocks are much decomposed, is too well known to require comment. The beds immediately resting upon the traps are of older date than the nummulitic limestone. The trap rests unconformably on neocomian and jurassic formations.

In Sind the very thin representatives of the Deccan traps may, of course, only represent a small portion of the period during which the volcanic rocks were in process of accumulation further to the eastward. One band rests conformably upon cretaceous beds, the exact horizon of which has not been ascertained, and is overlaid, equally conformably, by strata which are of very old tertiary date, if indeed they be not intermediate between tertiary and cretaceous, whilst a second bed of trap is found about 700 feet lower, interstratified with cretaceous sandstones.

It will be seen, therefore, that whilst it is clear that the Deccan traps were poured out in the interval between middle cretaceous and lower eocene, the evidence tends to shew that the lowest volcanic outbursts were of cretaceous age, because they appear to differ less in age from the middle cretaceous beds of Bágh than the highest traps do from the lower eocene formations of Surat. That an immense period of time was occupied by the accumulation of the successive volcanic outbursts is manifest; long intervals must have elapsed between successive flows in all those cases in which fossiliferous sedimentary beds

[1] For explanation of these terms, see a subsequent chapter on the geology of Sind.
[2] Wynne: Mem. G. S. I., IX, p. 66.

are intercalated, for these intervals were sufficient to enable lakes to be formed and stocked with life, and in other cases for rivers to cut beds in the lava flows, and to fill up those beds with gravel and sand. It is by no means improbable that whilst the lower lava flows were upper cretaceous (turonian or senonian) the uppermost, including the inter-trappean beds of Bombay, may have been contemporaneous with the lowest eocene deposits. As a whole, however, the Deccan trap series appears to be more probably upper cretaceous than tertiary.

Probable conditions prevailing during Deccan trap epoch.—Recapitulating the whole evidence, so far as it is presented to us by the observations hitherto made, we find that a great area of the Indian Peninsula, in times subsequent to middle cretaceous, formed part of a land surface, very uneven and broken in parts, but apparently chiefly composed to the eastward of extensive plains, which, by some slight changes of level preceding the volcanic period, were converted into lakes. There is much probability that springs charged with silica were common either at this epoch or shortly after. The lakes had apparently been drained, and the deposits, which had accumulated in them, had locally been subject to denudation before the first outbursts of lava took place; these occurred at considerable intervals, small and very shallow lakes or marshes being formed in the meantime by the interruptions to the drainage produced by lava flows, or by changes of level accompanying the volcanic eruptions. In these lakes a rich fauna of fish, mollusca, entomostracous crustacea and water plants existed, whilst a varied and probably a rich vegetation occupied the surrounding country. There is evidence of the existence of insects and of reptiles (whether terrestrial or aquatic has not been determined), but hitherto no remains of mammals or birds have been found— a circumstance which by no means proves that they did not exist. Fresh flows of lava filled up the first lakes, and covered over the sedimentary deposits which had accumulated in the waters; but these very flows, by damming up other lines of drainage, produced fresh lakes, so that several alternations of lava and sedimentary beds were produced in places. Gradually the lakes seem to have disappeared; whether the lava flows succeeded each other so rapidly that there was no time for the accumulation of sediment in the interval, or whether, as is more probable, the surface had been converted into a uniform plain of basalt by the enormous lava streams which had been poured out, it is difficult to say, but no further traces of life have hitherto been found until towards the close of the volcanic epoch. It is possible that at the end, as at the commencement of the period, the intervals between eruptions became longer, and the animal and vegetable

life which may have been seriously diminished, or altogether driven out of the country, during the rule of igneous conditions, resumed its old position, but a great change had taken place in the long interval, the old lacustrine fauna had died out, and the animals and plants which now appeared in the country seem to have differed from those which had formerly occupied it. Lastly, in the north-western portion of the area, parts of the volcanic country were depressed beneath the sea, and marine tertiary deposits began to be formed from the detritus of the extinct volcanoes and their products. A great tract of the volcanic region, however, appears to have remained almost undisturbed to the present day, affected by subaërial erosion alone, and although probably for a time at a lower elevation than at present, never depressed beneath the sea-level.

CHAPTER XIV.

PENINSULAR AREA.

TERTIARY ROCKS.

Distribution of tertiary strata in the Peninsula — East coast: Cuddalore sandstones —West coast: Travancore limestones, sands, clays and lignite — Ratnagiri plant beds — Tertiary beds of Guzerat — Eocene beds of Surat — Higher tertiaries of Surat and Broach — Kattywar — Ossiferous beds of Perim Island — Cutch — Subnummulitic group — Gypseous shales — Nummulitic — Arenaceous group — Argillaceous group — Upper tertiary — Jesalmir.

Distribution of tertiary strata in the Peninsula.—The tertiary rocks of the Indian Peninsula cover but a small area, and are confined to a narrow fringe found in places in the neighbourhood of the coast. The ossiferous deposits of the Indian river valleys are now considered post-tertiary, and the geological age of the laterite or iron clay which is found capping many of the Indian plateaus is quite uncertain, and it is, therefore, best to describe all forms of lateritic rock separately.

In the extrapeninsular area, in Burma, Assam, the Punjab, and especially in Sind, on the other hand, there is a superb development of tertiary rocks, and although, for the sake of uniformity of arrangement, it is best to describe the tertiary beds of the Peninsula apart from those found beyond the Indus and Ganges, it must be understood that the only important fossiliferous marine formations in the Peninsula, of later date than the Deccan traps, are found in Western India, and are a mere prolongation to the south-east of the Sind and Cutch tertiaries.

There are but five regions of India in which tertiary rocks will require to be noticed in the present chapter. These regions are all on the outskirts of the peninsular area, and all in which marine fossils have been detected are either along the west coast, or on the border of the Indus valley. In the interior of the Indian Peninsula no trace of a marine tertiary formation has hitherto been detected, and it appears probable that the peninsular area was land during tertiary, as it was for the most part during mesozoic and probably in palæozoic times. The

tertiary outcrops on the margin of Peninsular India may be thus classed—

(1)—East coast of the Peninsula (Cuddalore sandstones).

(2)—West coast of the Peninsula, Travancore (and Ratnagiri ?).

(3)—Guzerat (Surat, Broach, Perim Island, Kattywar).

(4)—Cutch.

(5)—Jesalmir.

Only three of these—the Cuddalore sandstones, the tertiary beds of Guzerat, and those of Cutch—are sufficiently developed or sufficiently known to be of importance; of the other occurrences but little has been ascertained.

East Coast: Cuddalore sandstones.—Along the eastern coast of the Peninsula, from the neighbourhood of Rájámahendri to beyond Tanjore, and probably farther south, a peculiar formation, consisting chiefly of sandstones and grits, is found underlying the laterite which forms a low slope on the edge of the coast alluvium. This sandstone formation has received several local names, but has of late years generally been known as the Cuddalore sandstone,[1] from being well developed in the neighbourhood of the civil station of Cuddalore (Gudalúr) on the coast, about 100 miles south of Madras.

The greater portion of the Cuddalore group, throughout the area in which it is found, consists of gritty and sandy beds, sometimes highly ferruginous, and coloured of various tints of yellow, brown, red and purple, sometimes white or pale coloured, and not unfrequently mottled. In some cases the rock is argillaceous, and occasionally thin bands of clays or shales are interstratified. The beds are soft, loose-textured, and, as a rule, ill-consolidated, being rarely sufficiently compact to be used as building stone. Bands of conglomerate have been found.

As already stated, these beds have been traced throughout a large portion of the east coast. Their most northerly extension known is between Vizagapatam and Rájámahendri. The coast north of Vizagapatam as far as the Chilka lake has not been examined geologically, and throughout Orissa no outcrops of the Cuddalore beds have been detected; but there is a possibility that they may be represented by some clays and sandy beds associated with the laterite of Midnapur.[2] There is rather more probability that the sandstones, grits and clays, already briefly mentioned[3] in the description of the Rániganj coalfield as occurring

[1] For further information, see H. Blanford: Mem. G. S. I., IV, pp. 165-179; King and Foote: *ib.*, pp. (256), (268); and R. B. Foote: *ib.*, X, pp. 59-60.

[2] Mem. G. S. I., I, p. 268.

[3] *Ante*, p. 184.

east of Ránigan j, and extending to the northward as far as Soory in Birbhúm, belong to the same group as the tertiary sandstones of Madras.

From the neighbourhood of Rájámahendri the Cuddalore beds have been mapped at intervals for fully 500 miles to the southward along the coast. They usually form a low slope, dipping at a very slight angle towards the eastward or in the direction of the sea, and are, as a rule, much covered and concealed by laterite. To the westward they rest indifferently upon rocks of various ages, metamorphic, jurassic, or cretaceous, but always unconformably, and they very often terminate in this direction in a low scarp. To the eastward they disappear in places, with their capping of laterite, beneath the alluvium of the coast, but they quite as often, especially to the southward, terminate in a small cliff. Their outcrop is repeatedly interrupted by the broad alluvial valleys of rivers, and in some places, as for nearly 100 miles south of Madras, they appear to be wanting altogether, whilst in other parts of the country they form a broad tract raised above the general level, usually sandy and infertile, occasionally, as near Cuddalore, no less than 25 miles wide from east to west, but in general much less. South of Tanjore these beds have not been mapped, but there is no doubt that they extend for a considerable distance towards Cape Comorin.

From the paucity of sections and the extent to which the Cuddalore sandstones are concealed by laterite and sandy soil, their absolute thickness can nowhere be estimated with accuracy. The scarp in which they terminate to the westward is sometimes as much as 100 feet high, and they must be somewhat thicker than this, but it is doubtful if they attain any considerable thickness. They are perfectly undisturbed, and have all the appearance of being a comparatively late formation.

The only fossils found in the Cuddalore beds consist of exogenous silicified fossil wood, some of which is coniferous, and has been described under the name of *Peuce schmidiana*.[1] The genus *Peuce* is not acknowledged by all palæo-botanists, and it appears too ill defined to justify any conclusions as to the age of the rocks being founded upon its occurrence.

This silicified wood is especially abundant at Tiruvakári (Trivicary), about 14 miles west-north-west of Pondicherry, whence the name of Trivicary grits applied by some writers to the local development of the Cuddalore sandstones. The trunks of trees occurring at this place are of large size, one having been found as much as 100 feet in length, whilst stems 15 to 20 feet long and 5 or 6 feet in girth are not uncommon. They occur prostrate, embedded in ferruginous grit.

[1] Schmidt and Schleiden: "Uber die Natur der Kieselhölzer," Jena, 1855, pp. 4, 36.

The age and mode of origin of the Cuddalore sandstones are obscure, as but little importance can be attached to the identification of one generic form of coniferous wood. They are quite unconformable to the cretaceous beds, which they overlap in a most irregular manner, as near Pondicherry, where, near the town itself, they form the plateau known as the "Red Hills," and rest on beds of the Arialúr group; 6 miles farther westward and west of the belt of cretaceous rocks, they are seen near Tiruvakári resting on Utatúr beds, whilst a few miles farther west they completely overlap the cretaceous rocks and rest on gneiss. Fragments derived from the cretaceous beds and containing cretaceous fossils have been found near Tanjore. Near Rájámahendri the Cuddalore sandstones similarly overlie the Deccan traps, the jurassic rocks and the gneiss. It is safe, therefore, to conclude that the sandstones are of tertiary age, but it is impossible to assign them a definite place in the tertiary series.

The origin of these rocks is as obscure as their date. Occurring as they do parallel with the coast, it is natural to suppose that they are of marine origin, and have been formed near the shore when the level of the land was somewhat lower than it now is, although the general contour of the coast was the same. But the complete absence, so far as is known, of all marine remains, is not easy to explain. Coarse sandstones and grits are usually unfossiliferous, but in beds which have undergone so little change, some casts of shells, at least, would probably be found in the more argillaceous strata if they were of marine origin. At the same time it is not easy to conceive any other probable mode of formation. It is difficult to suppose that the western coast of the Bay of Bengal can have formed part of a river valley in tertiary times, and it is equally improbable that stratified grits, sandstones, and conglomerates, like those of the Cuddalore beds, can be a form of subaërial wash.

Travancore limestones, sands, clays, and lignite.—The only information yet published on the occurrence of tertiary beds near Travancore is comprised in some notes supplied by General Cullen to Dr. Carter, and published by the latter in his "Summary of the Geology of India."[1] Beneath the laterite of the neighbourhood of Quilon (Kulam), at a depth of about 40 feet from the surface, grey fossiliferous limestone (or dolomite according to General Cullen) is found, partly compact and partly loose and rubbly. This limestone is exposed beneath

[1] Journal, Bombay Br. R. A. S., V, p. 301; and "Geological Papers on Western India," pp. 740, 743, and footnote, pp. 743-744. This footnote is an addition to the original summary. Travancore has not yet been examined by the Geological Survey.

a laterite cliff near the coast 4 or 5 miles north-east of Quilon, and the same rock has been found in the neighbourhood of the town at a depth of about 40 feet in numerous wells, many of which were sunk or deepened by General Cullen for the purpose of ascertaining the presence of the limestone. Further south, near Varkalay, 12 to 14 miles south of Quilon, the cliffs on the coast expose, beneath the laterite, beds of brightly coloured sand and clays with bands of lignite. The sandy beds overlie the lignites and clays. The lignite beds abound in fossil resin and iron pyrites, both in lumps of considerable size.

The limestone contains marine shells in abundance, amongst which the following species were recognised by Dr. Carter :—

Strombus fortisi,	*Ranella bufo,*
Cassis sculpta,	*Conus catenulatus,*
Voluta jugosa,	*C. marginatus,*

Cerithium rude,

besides species of several other genera resembling forms found in the tertiary beds of Sind and Cutch. A species of Orbitolites (?) was also described by Dr. Carter as *O. malabarica.* All the mollusca identified belong to species occurring also in Cutch and Sind, and, so far as is known, in beds of later date than the nummulitic limestone. No plants appear to have been collected from the lignite beds.

Further examination of the Travancore beds and comparison of the fossils is, however, necessary before the age of these rocks can be considered as ascertained with sufficient precision. The interest attached to the subject is, of course, increased by the possibility of these fossiliferous tertiary deposits of Travancore representing the unfossiliferous Cuddalore sandstones; the relations between the two, whether they represent each other or not, will perhaps be determined by tracing both to the southward.

Ratnagiri plant beds.—Another deposit of obscure date and origin has been found beneath laterite at Ratnagiri (Rutnagherry) on the western coast.[1] There is but little evidence to connect this deposit with the Travancore beds, but, owing to some similarity of mineral character, the presence of lignite in both, and the circumstance that both underlie laterite, they have been classed together.

In various quarry and well sections near the town of Ratnagiri, there are found, beneath a considerable thickness of laterite, (35 feet in one case,) white or blue clays with thin carbonaceous seams. Some of the clay is said to be sandy or gravelly; above the deposit is a layer of

[1] Carter: Journal, Bom. Br. R. A. S., V, p. 626, and "Geological Papers on Western India," p. 722, footnote; Wilkinson: Rec. G. S. I., IV, p. 44.

hard ironstone, about an inch thick in places, but said sometimes to be thicker. In the clay and lignite fruits and leaves are found, together with mineral resin and pyrites as at Travancore. No specimens of the organisms found appear to have been collected.

The beds are only a few feet thick (27 in one section measured by Dr. de Crespigny), and rest unconformably upon Deccan trap.

Tertiary beds of Guzerat.—Near the coast of the Gulf of Cambay, in the country between the rivers Tapti and Narbada, a few outcrops of the marine tertiary rocks are found, resting upon the Deccan trap, although the greater part of the country west of the trap area is concealed by a thick coating of "black soil." These outcrops are the commencement of the great tertiary belt which, fringing the coast of Kattywar and Cutch, and extending in patches over the older rocks inland, rises into a lofty range of hills on the western frontier of Sind, and extends to the Himalayas in one direction and through Persia to the Caucasus on the other.

Recently, the examination of Sind has enabled the very fine series of tertiary rocks exposed within that province to be classed in the following groups.[1] :—

1. Manchhar or Siwalik . . .	Pliocene and upper miocene,
2. Gáj	Miocene,
3. Nari	Lower miocene or upper eocene,
4. Khirthar	Eocene,
5. Ranikot	Lower eocene,

and some attempt has been made to correlate the groups occurring in other parts of India. Until the fossils can be thoroughly examined, however, it will be impossible to determine the relative position of the different beds in distant regions with accuracy. It is evident that the groups named above are more or less local, and although they are perfectly distinct in parts of Sind, there is a tendency to a passage between all of them in other parts of the province, and it is quite uncertain how far the tertiary rocks beyond the limits of Sind can be arranged in the same sub-divisions. At the same time, as many characteristic fossils are known from all the groups named, these divisions serve as a standard to which the tertiary strata of Western India, and perhaps of the countries to the north-east and east of the Bay of Bengal, may be approximately referred.

The tertiary rocks in Surat and Broach[2] are almost confined to two tracts of country, separated from each other by the alluvium of the

[1] For particulars see Chapter XIX, on the Geology of Sind.

[2] For a fuller description, see Mem. G. S. I., VI, pp. (223)-(227) and (356)-(373).

river Kim, a small stream running to the sea from the Rájpipla trap area. The southern area is smaller, extending about 10 miles north from the Tapti river, and being about 15 miles broad from east to west the other area, between the Kim and Narbada, extends about 30 miles from north-east to south-west, and about 12 miles across where widest. In both, the few good exposures of rock which occur are to the eastward.

Eocene beds of Surat.—At the base of the tertiary formations north-west of Surat are thick beds of ferruginous clay, assuming, where exposed, the characteristic brown crust and pseudo-scoriaceous character of laterite,[1] from which they differ in no respect. These beds at first sight appear to be of volcanic origin, an idea which is strengthened by the neighbourhood of the traps on which they rest, but close examination has shewn that they are really sedimentary deposits, although composed, in all probability, of materials derived from the disintegration and denudation of the trap. With them are interstratified beds of gravel or conglomerate, containing agate pebbles, (the agates being derived from the traps,) and limestone, sometimes nearly pure, but more frequently sandy, argillaceous or ferruginous, and abounding in nummulites and other fossils. The thickness of the whole can only be roughly estimated as between 500 and 1,000 feet.

These beds are well seen on the banks of the Tapti below Bodhán, a village 18 miles east by north from Surat. They extend thence to the northward through Tarkesar to the Kim alluvium, and again north of the Kim to the neighbourhood of a village called Wágalkhor, about 24 miles north-north-east of Bodhán, and 17 east by south of Broach. North of this they appear to be overlapped by higher beds.

The nummulitic limestones and their associates are distinctly unconformable to the underlying traps, and rest upon the denuded edges of the latter. Amongst the fossils found in the lower tertiary beds are *Nummulites ramondi*, Pl. XV, fig. 12, *N. obtusa* (fig. 13), *N. exponens* (or *N. granulosa*, fig. 14,) *Orbitoides dispansa* (fig. 8), and some other species which are common in the Khirthar beds of Sind, together with *Ostrea flemingi*, *Rostellaria prestwichi*, and *Natica longispira*, which in Sind are particularly characteristic of the Ranikot group, and *Vulsella legumen*, Pl. XV, fig. 4,) found in both. Some other fossils have been identified with species found at a higher horizon, but the identification appears doubtful. The nummulitic beds of Surat and Broach may safely be classed as eocene.

Higher tertiaries of Surat and Broach.—Above the limestones and lateritic beds there is found a great thickness of gravel, sometimes

[1] See next chapter.

cemented into conglomerate, together with sandy clay and ferruginous sandstone, often calcareous. These higher beds are poorly exposed in the Tapti river near Galla and Karjan, 15 miles above Surat, and in the Kim river between Kimamli and Elao, about halfway between Surat and Broach, but they are well seen in the stream which runs past Ratanpur, east of Broach. Here they consist chiefly of sandstone, gravel, and conglomerate, with occasional beds of red and white clay and shales. The pebbles in the gravels and conglomerates consist chiefly of agates and quartzose minerals derived from the trap, and from some of these beds near Ratanpur, east of Broach, the agates and carnelians are obtained which have from time immemorial supplied the lapidaries of Kambayat (Cambay). At the base of the tertiary beds in this direction is a coarse conglomerate composed of large rolled fragments of basalt, but it is uncertain whether this bed belongs to the upper tertiary group or to the lower tertiaries, as, owing to the few sections exposed, it is not quite clear whether the lower eocene beds are completely overlapped to the northward, or merely represented by unfossiliferous beds of a different mineral character. Like the underlying beds, the higher tertiary strata have a steady dip to the westward, and the thickness of the whole tertiary series exposed near Ratanpur appears to be between 4,000 and 5,000 feet, but this estimate is based on a very imperfect exposure of the rocks. Of course if, as appears possible, the lower beds are overlapped, the whole of this thickness consists of the upper members of the series.

No nummulites are found in these upper tertiary beds, and the few fossils discovered in them appear to differ from those in the nummulitic limestones below. The commonest organic remains are valves of *Balani*, which are also abundant in the Gáj (miocene) rocks of Sind. The abundance of *Balani* and the absence of *Nummulites* together form strong reasons for believing that the upper beds of Surat and Broach are of later date than eocene.

It is far from certain whether any pliocene beds are found in Eastern Guzerat. They occur in Kattywar and on Perim Island in the Gulf of Cambay, and further search may detect them in Surat and Broach.

Kattywar.—Very little indeed is known about the tertiaries of the Kattywar peninsula.[1] A belt of rocks, of later age than the Deccan traps, rests upon the volcanic series, and forms a fringe of varying width, extending throughout the coast line from the Gulf of Cambay to beyond Porbandar, and probably to the Gulf of Cutch. This fringe is

[1] The few details given are from a manuscript report by Mr. Theobald, and from Dr. Carter's "Summary of the Geology of India;" Jour. Bombay Br. R. A. S., V., pp. 300, 306, 313; and "Geological Papers on Western India," pp. 696, 737, 743, 756, &c.

generally from a mile to about 12 miles broad; but the tertiary beds extend farther inland in places, as opposite the Gir and near Porbandar. They probably also, as in Cutch, lap round the older rocks and reappear to the northward on the borders of the Ran.

Some nummulitic limestone occurs near the base of the tertiary series, and above the limestone there is found a series of argillaceous beds, consisting chiefly of blue clay with bands of sandstone and shelly grit and coarse rubbly limestone, the latter containing amongst other fossils *Balani* and *Venus granosa* (Plate XVI, fig. 7,) both of which are in Sind common in the Gáj (miocene) beds. The clays are of considerable thickness, for at Gogo, on the east coast of Kattywar, a boring was made in them to a depth of 344 feet without any lower rocks being reached. With these clays ossiferous sandstones and coarse conglomerates are said to be associated. If these ossiferous beds, as is possible, represent the Manchhar (or Siwalik) group of Sind, the representatives of the Manchhar and Gáj beds must be interstratified in Kattywar;—by no means an improbable circumstance, for, as will be seen, they pass completely into each other in Sind.

Above the clays and ossiferous sandstones are horizontal beds of limestone and calcareous grit, with occasional layers of clay. One form of this rock is the Porbandar stone, called miliolite by Dr. Carter, largely used for building in Bombay, and mainly composed of *Foraminifera*. This limestone is extensively false-bedded; it is porous, soft, and easily worked. The only fossils found besides *Foraminifera* are land shells of recent species, of which a few occur in the upper beds where the *Foraminifera* are scarce. The age of this formation is uncertain, and it may be post-tertiary, but as alluvial deposits rest upon its abraded surface, it is for the present classed as possibly of late tertiary age.

Ossiferous beds of Perim Island.—The small island of Perim[1] in the Gulf of Cambay, opposite the mouth of the Narbada, but nearer to the coast of Kattywar than to that of Broach, has become famous from the circumstance of fossil bones having been discovered in considerable quantities upon its shores. The island is simply a reef of rock about 1½ miles long, barely half a mile broad at high water, and covered with blown sand. This island itself is surrounded by an extensive reef, dry at low water, and composed partly of conglomerate containing rounded blocks of sandstone, varying from 3 feet in diameter downward, and partly of a coarse sandstone with agate pebbles. Nodular concretionary pebbles of argillaceous sandstone and rolled fragments of fossil wood,

[1] By some European writers on geology and zoology, this island is confounded with another of the same name, but far better known, in the Straits of Babelmandeb at the entrance to the Red Sea. For a description of the geology of the Indian Perim Island and references to former describers, see Mem. G. S. I., VI, pp. (180), (373).

bored by *Teredo,* occur with the large boulders. Both forms of rock are calcareous. Some fine sandstones also occur.

The beds are in general horizontal, and they are, as a rule, much obscured by a deposit of fine mud. Bones occur in the coarse sandstone and in the conglomerate, and the following species of mammals have been identified[1] :—

Mastodon latidens (Pl. XVII, fig. 4).	*Brahmatherium perimense* (Pl. XVIII, fig. 5).
M. sivalensis (fig. 6),	*Camelopardalis*, sp.
M. perimensis (fig. 3).	*Capraperimensis.*
Dinotherium indicum.	*Antilope*, sp.
Acerotherium perimense.	*Sus hysudricus.*
Rhinoceros, sp.	

These beds appear to be slightly older than the typical Siwalik strata.[2]

Cutch.—The tertiary rocks in the Cutch (Kachh or Kach) peninsula occupy a belt varying in breadth from about 4 miles to 20, between the alluvium near the coast and the older rocks in the interior of the country. Tertiary formations also fringe the Deccan traps and jurassic beds on the borders of the two openings by which the Ran[3] to the north of Cutch communicates with the sea east and west of the province[4]; and patches of the same tertiaries are found here and there on the shores of the Ran, not only in the main region of Cutch itself, but also around the detached hilly tracts or islands, Pachham (Putchum), Kharir (Kurreer, &c., and in Wagad (Wagur). The evidence of unconformity between the eocene rocks and the Deccan traps is, therefore, very strong in Cutch, for the former existence of numerous volcanic vents of the Deccan age throughout the jurassic area is proved by the presence of intrusive cores of basalt, and it is almost certain that the greater part, if not the whole, of the jurassic region must have been overflowed by trap in later cretaceous times.[5] The lava flows must have been, however, completely swept away from the surface of the country, and the underlying jurassic rocks exposed, and probably in places largely eroded, before the eocene marine beds were deposited. Despite this strong evidence of unconformity, there is every appearance, along the southern border of the trap area, of the tertiary beds resting conformably on the lava flows of the Deccan period.

[1] Lydekker: Rec. G. S. I., IX, p. 91.

[2] The relations of the mammaliferous later tertiary deposits of India will be discussed in the chapter on the Siwaliks of the sub-Himalayan region.

[3] See Chapter XVII.

[4] Cutch, it should be remembered, is an island in the monsoon, when the Ran is covered by water.

[5] This view is opposed to Mr. Wynne's opinion. He considers that the lower eocene beds are conformable to the traps, and that the overlap is due to the traps never having existed in Northern Cutch.—Mem. G. S. I., IX, p. 72.

The tertiaries of Cutch are far better known than those of Guzerat and Kattywar; the materials for the first descriptions of marine fossils from the later Indian deposits having been furnished by the rocks of the present province. Attention was first directed to the Cutch tertiaries through the labours of Captain Grant, who carried with him to England a considerable collection of tertiary organic remains, together with the jurassic fossils mentioned in a former chapter. In accordance with the ideas prevailing amongst geologists at the time, he separated nummulitic rocks from the true tertiaries on his map,[1] and the same distinction was preserved in the description of the fossils, but subsequently all the forms described were classed as eocene by MM. D'Archiac and Haime.[2] The rocks of Cutch were mapped in 1867-69 by Messrs. Wynne and Fedden, and described by the former[3]: it was found that several distinct groups could be recognised, and that the fossils of these groups differed. It was afterwards discovered that the groups corresponded very closely to those subsequently determined in Sind, and although some of the fossils described as tertiary by Sowerby in the appendix to Captain Grant's Memoir were apparently derived from beds interstratified with the nummulitic limestone, a large proportion are from a higher horizon, and are not in all probability older than miocene. The succession (descending) of the rocks in Cutch, according to Mr. Wynne, is the following, the probable Sind representatives[4] being appended in each case. The supposed European equivalents differ somewhat from those originally suggested[5] before the corresponding beds in Sind had been examined:—

	Cutch.		Sind.	European equivalents.
	Alluvium, blown sand, &c.		Alluvium, &c.	*Pleistocene and recent.*
Tertiary.	Upper tertiary (unconformity)	200 to 500 ft.	Manchhar	*Pliocene and upper miocene.*
Tertiary.	Argillaceous group	800 to 1,200 „	Gáj	*Miocene.*
Tertiary.	Arenaceous group	130 „	Nari (?).	*Lower miocene and upper eocene.*
Tertiary.	Nummulitic group	700 „	Khirthar	*Eocene.*
Tertiary.	Gypseous shales	100 „	Ranikot	*Lower eocene.*
Tertiary.	Subnummulitic	100	Ranikot	*Lower eocene.*
	Stratified traps		Trap	*Upper cretaceous.*

Subnummulitic group.—This group consists chiefly of peculiar soft argillaceous beds of purple and red, mottled with white, laterite of various kinds, and coarse sandstones. There are also some shales with

[1] Trans. Geol. Soc., Ser. II, Vol. V. pp. 300, 302, Pl. XX, XXIV, XXV, XXVI.
[2] Descr. An. Foss. Gr. Numm. de l'Inde.
[3] Mem. G. S. I, IX, pp. 66-81, &c.
[4] See subsequent chapter on Sind.
[5] Mem. G. S. I., IX, p. 48.

impressions of leaves and carbonaceous layers, and occasionally with gypsum. The beds of this horizon are distinguished by brilliancy of colouring; white, red, lavender, purple, and orange tints prevailing.

Some of the peculiar argillaceous beds have a distinctly volcanic aspect, but as they are much decomposed, it is impossible to say that they are really of eruptive origin. The occurrence of these peculiar beds away from the traps, in places where there is good reason to suppose that the traps were removed by denudation in pretertiary times, and the fact that beds reconsolidated from trap fragments must, when decomposed, frequently be undistinguishable from a disintegrated eruptive rock, render it probable that these soft mottled beds are of sedimentary origin and composed of volcanic detritus. Fossils are rare in the subnummulitic group, which extends along the southern edge of the traps in Cutch, overlapping the volcanic rocks, however, near Lakhpat to the westward, and resting upon jurassic rocks. The same group is represented in several small patches, also deposited upon jurassic beds, on the borders of the Ran, both on the mainland of Cutch and on some of the detached hills or islands, especially south of the hills in Pachham, Kharir, Bela, and Chobar, and intervening in the hollow between two ranges on the first-named. The group is nowhere more than about 200 feet thick, and it frequently does not exceed 20 feet. Alum is manufactured at Mhar in Western Cutch from a pyritous shale associated with the present sub-division.

Above the subnummulitic beds there are in places from 50 to 100 feet of fine laminated shales, bituminous and often pyritous, with fragments of wood and leaf impressions. All the above rocks are, by Mr. Wynne, classed apart from the true tertiaries, and with the bedded traps, It appears more probable, however, and more in accordance with the sequence in Sind, where, as in parts of Cutch, the beds are, as a rule, perfectly conformable, to consider the main break in the series as taking place between the traps and the next formation in ascending order.

Gypseous shales.—This is a local and unimportant sub-division, not more than from 50 to 150 feet in thickness, occurring in Western Cutch around the Gaira hills, and in a few other places. It consists of shales with calcareous nodular bands, with some beds of laterite, and with much gypsum. Some of the marly beds abound in *Nummulites* and other *Foraminifera* with oysters, &c.

Nummulitic.—The next group is of more importance, being the representative of the massive nummulitic limestone of Sind. In Cutch these beds consist of pale yellow and white impure limestones in bands

of no great thickness, interstratified with marls and sandy beds. The upper portion consists chiefly of marls, limestones being more abundant below. *Nummulites* and *Alveolinæ* abound, and Echinoderms of several kinds; corals and mollusca are locally common. The nummulites of Cutch are, however, almost confined to the western part of the province, and occupy a band extending from Lakhpat, at the extreme north-west of the Peninsula, around the Gaira Hills, the western termination of the Deccan trap range in Cutch.

Arenaceous group.—Upon the nummulitic limestones and their associates there is usually found a thin and unimportant band of light coloured or white sand and sandy shales, having at the base some finer silty shales, dun or blue in colour. These sandy beds are soft, friable, and obliquely laminated. In the lower portion of the group the carapace of a small crab and casts of bivalve shells have been found, in the upper part impressions of dicotyledonous leaves occur. This group, like the nummulitic beds, is only found in Western Sind.

Argillaceous group.—The next group in ascending order is the most important of all the Cutch tertiary beds, being the best developed and the most fossiliferous, and it is this group which yielded the bulk of the fossils described as "tertiary" in the appendix to Captain Grant's paper, although it appears probable that there was amongst these fossils some admixture of species from a lower horizon. Until the whole of the Cutch and Sind fossils are thoroughly compared and determined, some doubt must remain as to the original horizon of a few Cutch species, but when the forms are common to the Gáj beds of Sind, and are not known to occur in older formations, it may fairly be inferred that they are probably restricted to the same horizon in Cutch.

The rocks of the argillaceous group consist of sandstones at the base with a few nodular marly and ferruginous beds often containing *Turritellæ*, *Venus granosa* (Plate XVI, fig. 7) and *Corbulæ*. Above the sandy beds are marly limestones and shales, next calcareous grits, and then a considerable thickness of shales, clays, and marls. The most fossiliferous beds are the marly limestones and shales. In mineral character, as in fossils, these beds appear precisely to resemble the Gáj group of Sind. The argillaceous group is more extensively developed in Cutch than the nummulitics are; it is found not only in the west of the province around the extremity of the jurassic and trap area, but eastwards, resting upon the subnummulitic group, as far as the neighbourhood of Mándvi, or about half way across the province. To the westward, however, the present group is overlapped by the next in ascending order.

Upper tertiary.—This is apparently the representative of the Siwalik rocks in the Sub-Himalayan tract, and of the Manchhar beds in Sind; it is widely developed in Cutch, and covers a large area, but it is very ill seen, being greatly concealed by alluvial deposits. The principal beds are conglomerate, more or less ferruginous, at the base, followed in ascending order by thick brown sands and obliquely laminated, nodular, calcareous and sandy clays. Marine beds with large oysters are intercalated, as in Southern Sind. It will probably be found on further examination that this uppermost tertiary group in Cutch, as in Sind, passes down into the underlying sub-division in places, although to the eastward the latter appears to have been denuded before the deposition of the former. The "upper tertiary" group extends throughout Southern Cutch from east to west, resting on the older tertiaries to the westward, but gradually overlapping them and the traps to the eastward, and resting upon jurassic rocks in the extreme east of the province.

Jesalmir.—About 30 miles west-north-west of Jesalmir, on the road to Rohri in Sind, the track, which from Jesalmir as far as this passes over jurassic rocks, crosses a steep scarp of nummulitic limestone of no great height. The rock has a very low dip to the westward, and rests unconformably upon the jurassic beds: it is traced for a few miles further west before it disappears beneath the sands of the "Thar," or desert of blown sand-hills, which forms the western boundary of Sind. A few small patches of limestone, however, appear from beneath the sand-hills further to the westward, and it is probable that the rock continues in this direction to Rohri, where there are low hills of the formation. The scarp extends for many miles to the north-east; to the south-west it is covered by sand-hills.

In the limestone some of the common nummulites, such as *N. ramondi* (Pl. XV, fig. 12), *N. beaumonti* and *N. spira*, occur in abundance. These are amongst the forms characteristic of the great nummulitic limestone (Khirthar) formation of Sind. The outcrop in fact, although east of the Indus alluvial area, is evidently merely an outlier of the extra-peninsular rocks. Whether it is more extensively developed to the northward in Baháwalpur remains to be ascertained.

CHAPTER XV.

PENINSULAR AREA.

LATERITE OR IRON CLAY AND LITHOMARGE.

Laterite — General characters and composition — Varieties of laterite, high-level and low-level types — Lithomarge — Reconsolidation of laterite — Infertility of lateritic surface — Distribution and mode of occurrence of the high-level laterite or iron clay in the Western Deccan, Southern Máhratta Country, hills near the Máhánadi valley, Karakpur hills, Bundelkhand and Rájmahál hills — Distribution, &c., of the low-level laterite — Theories of origin of high-level laterite — Geological age — Possible Ohypothesis of origin —Origin of low-level laterite — Its age.

Laterite.—All who have paid any attention to the geology of India must be familiar with the term "laterite," and no one can have travelled far in India without meeting with the substance itself. Although it is difficult to conceive that a rock, so widely spread in India, can be peculiar to the country, and to some other parts of South-Western Asia,[1] it is uncertain if anything precisely similar has hitherto been detected elsewhere; and nothing of the kind is known in Europe. The description of laterite, given in many geological works, is far from accurate,[2] although the rock has been well described by several Indian geologists.[3]

[1] It is said to be extensively developed in Malacca and Sumatra, and some occurs in Burma. Voysey states that it is found at the Cape of Good Hope. It is an extraordinary fact that no laterite has been detected in Abyssinia, where the rocks throughout a large area of country are precisely similar to those of the Bombay Deccan.

[2] For instance, in Lyell's Elements (edn. 1865), pp. 598-600, this substance is classed with igneous rocks, and thus defined: "A red jaspery, brick-like rock, composed of silicate of alumina and oxide of iron, or sometimes consisting of clay, coloured with red ochre." At the same time we are indebted to Lyell for the very valuable suggestion, that the rock may be derived from the disintegrated detritus of lava and scoriæ washed down by water.

[3] It would be difficult to give a description of any rock more clear and accurate than Newbold's account of the laterite of Bidar: J. A. S. B., XIII, p. 989 (1844). See also J. A. S. B., XIV, p. 299, and the description of the rock generally by the same author in his "Summary of the Geology of Southern India": Jour. Roy. As. Soc., VIII, p. 227 (1846).

The descriptions of laterite scattered through the writings of various Indian geologists are too numerous to quote. Amongst the more important are the following:—

Buchanan: Journey from Madras through Mysore, Canara, and Malabar, II, p. 440 (1807).

From the very large area in India, which is superficially covered with laterite, it becomes an important formation; and a treatise on Indian geology would be imperfect without a full description of the rock. The geological age is, in many cases, obscure. Although there can be but little doubt that some forms of laterite date from tertiary, and perhaps from eocene, times, other forms are unquestionably post-tertiary, some being in process of formation at the present day; and as the rock is usually unfossiliferous, it appears best to describe all the varieties together at the commencement of the section relating to post-tertiary or quarternary rocks.

General characters and composition.—Laterite, in its normal form, is a porous argillaceous rock, much impregnated with iron peroxide, which is irregularly distributed throughout the mass, some forms of the rock containing as much as from 25 to 35 per cent. of metallic iron.

Stirling: As. Res., XV, p. 163 (1825).
Christie: Edinb. New. Phil. Jour., VI, p. 117 (1829); and Mad. Jour. Lit. Sci., IV, p. 468 (1836).
Calder: As. Res., XIX, p. 4 (1833).
Cole: Mad. Jour. Lit. Sci., IV, p. 100 (1836).
Voysey: J. A. S. B., XIX, p. 273 (1850).
Kelaart: Edinb. New Phil. Jour., LIV, p. 28 (1853).
Carter: Jour. Bom. Br. R. A. S., IV, p. 199 (1852); V, p. 264 (1857).
Aytoun: Edinb. Phil. Jour., IV, p. 67 (1856).
Buist: Trans. Bom. Geog. Soc., XV, p. xxii (1859).

The subject has also been frequently treated in the Memoirs of the Geological Survey, especially in Vol. I, pp. 69, 265, and 280; II, p. 78; IV, p. (260); X, p. 27; XII, pp. 200-221 and 224; XIII, p. (222).

[1] The only analysis of laterite which appears to have been published is one by Captain James of a very richly ferruginous variety from Rangoon: J. A. S. B., XXII, p. 198.

The result given is the mean of three analyses made in the Laboratory of the School of Mines, London:

SOLUBLE IN ACIDS.	
Peroxide of iron	46·279
Alumina	5·783
Lime	·742
Magnesia	·090
Silica	·120
INSOLUBLE IN ACIDS.	
Silica (dissolved by potash)	6·728
Silica (by fusion)	30·728
Lime, iron, and alumina	2·728
Combined water alkalies and loss	6·802
	100·000

This is equal to 32·4 per cent. of metallic iron.

This iron exists either entirely in the state of hydrated peroxide (limonite,) or else partly as hydrated and partly as anhydrous peroxide. The surface of laterite after exposure is usually covered with a brown or blackish-brown crust of limonite, but the rock, when freshly broken, is mottled with various tints of brown, red, and yellow, and a considerable proportion sometimes consists of white clay. The difference of tint is evidently due to the segregation of the iron in the harder portions, the pale-yellow and white portions of the rock, which contain little or no iron, being very much softer, and liable to be washed away on exposure. Occasionally, the white portions have a brecciated appearance, and consist of angular fragments in a ferruginous matrix. In this case, the rock has not unfrequently a compact texture resembling jasper, but it is never so hard as a purely silicious mineral.

The iron peroxide not unfrequently occurs in the form of small pisolitic nodules, which, when washed out, are sometimes employed as iron ore. Veins and nests of black manganese have been observed by Newbold [1] in some laterites of the Deccan.

In many forms of laterite, the rock is traversed by small irregular tortuous tubes, from a quarter of an inch to upwards of an inch in diameter. The tubes are most commonly vertical, or nearly vertical, but their direction is quite irregular, and sometimes they are horizontal; they are usually lined throughout with a crust of limonite, and are often filled with clay, except near the surface. Besides these, there are sometimes horizontal cracks, sometimes expanding into small cavities, and giving an appearance of irregular stratification to the formation. In

The following are assays of the quantity of iron contained in the portion of laterite soluble in acids.

The first five and No. 8 have been made by Mr. Mallet for the present work; the other three are from the paper on the Laterite of Orissa, Mem. G. S. I., I, p. 288.

		Percentage of metallic iron.	Percentage of iron peroxide.
1	High-level laterite overlying Deccan trap, Amarkantak	35·6	50·8
2	Ditto from Main Pat, Sirgúja . .	16·6	23·7
3	Ditto from Baplaimali plateau, Kalahandi, south of Sambalpur . . .	15·	21·4
4	Ditto from top of Moira hill in the Karakpur range, south of Monghyr .	28·3	40·4
5	Ditto from Mahuagari hill, Rájmahál hills	15·8	22·5
6	Laterite (? high-level) from Kattywar, Western India	22·8	32·5
7	Low-level laterite from Daltola, Cuttack, Orissa . .	24·5	34·9
8	Ditto from near Cuttack . . .	25·6	36·5
9	Ditto from Tanjore	23·4	33·4

The difference between high-level and low-level laterite will be explained subsequently.

[1] J. A. S. B., XIII, p. 992.

the more massive forms of laterite some horizontal banding is usually present, the cavities being, however, beneath the surface, usually filled by clay, more or less sandy. The rock, when first quarried, is so soft, that it can easily be cut out with a pick, and sometimes with a spade, but it hardens greatly on exposure.

The exposed surface, whether vertical or horizontal, is characteristic and peculiar. It is extremely irregular, being pitted over with small hollows, caused by the washing away of the softer portions, and generally, though not always, traversed by the tubes and cavities just described; and, at times, it is so much broken up by small holes as to appear vesicular, whilst the crust of limonite forms a brown glaze, often mammillated or botryoidal, so that the rock has a remarkably scoriaceous appearance, and bears a very curious resemblance to an igneous product. It is not surprising that many observers should have looked upon laterite as volcanic; for not only does it present a remarkable superficial resemblance to a scoriaceous lava flow, but it is found, in several parts of India, associated with basalt and other igneous rocks. As will be shewn presently, however, laterite is never an original form of igneous rock; it is in all cases either produced by the alteration of other rocks, sometimes igneous, sometimes sedimentary or metamorphic, or else it is of detrital origin.

Varieties of laterite, high-level and low-level types.—Several writers have urged that the term "laterite" should be restricted to one form of the rock—that to which the name was originally applied by Buchanan.[1] This is the kind so extensively developed on the west coast of India, where it forms the surface rock of the country over wide tracts of the low lands near the sea. The particular locality in which the rock was first described by Buchanan has not been re-examined by other geologists, but there can be no reasonable doubt that he applied the name to a detrital variety. Before proceeding further, it will be well to explain the differences between the two forms.

The high-level laterite, sometimes known as non-detrital laterite, and distinguished by Mr. Foote as iron clay,[2] is found extensively on the highlands of Central and Western India. It is a rock of fine grain, and, apart from the irregular distribution of the iron, of nearly homogeneous structure, and not sandy. For this form the term "iron clay" was used by Voysey, one of the earliest describers, but he did not restrict the term to this variety; and he employed the same name for the laterite of Nellore, a low-level detrital form.

[1] l. c. note, p. 318. | [2] M. G. S. I., XII, p. 201.

The low-level or detrital laterite, which covers wide tracts in the neighbourhood of both coasts, generally contains grains of sand, and may often be recognised by including small rolled fragments of quartz, and occasionally larger pebbles. It is less homogeneous in structure than the high-level form, and it passes, by insensible gradations, into ferruginous sandy clay or gravel. It usually contains, in considerable quantities, small pisolitic concretions of iron peroxide, and occasionally it assumes the form of pisolitic iron ore, or of lateritic gravel, a mixture of small concretions and sand. The high-level laterite also contains pisolitic concretions in places, but they are not so generally present as in the low-level variety.

There are unquestionably some reasons for using different terms to designate these two forms of rock; and all geologists who consider that by the name of a rock not only its composition and structure, but also its origin, should be indicated, are justified in employing distinctive terms for the two, if they consider the difference of origin clearly made out. Unfortunately, the very use of two terms involves the hypothesis that the high-level form of laterite, containing no sand grains, has been produced simply by subaërial alteration of basalt or some other rock, whilst the low-level laterite is a formation of entirely different origin. This may be true, but, as will be shewn presently, it is not proved, and in some cases the origin of the high-level laterite appears to be clearly detrital. The fact is, that the two varieties pass completely into each other; both are often precisely similar in composition and structure, and specimens taken from one are frequently quite undistinguishable from those broken off from the other, although the rocks can usually be distinguished *in situ* by careful examination. How difficult it is, at times, to ascertain whether laterite is of detrital origin or not, is well shewn by the beds, which, as mentioned in the last chapter (p. 340), occur interstratified with the nummulitic limestones and gravels near Surat. These beds are sedimentary, for, in one of them, marine fossils were found; yet they are not in the least sandy, and they closely resemble the laterite or iron clay of the Bombay Deccan. The resemblance is so close, that, when these laterite beds were first examined by the Survey, they were supposed to be volcanic rocks, altered by surface action. The mistake, it should be added, was partly caused by an apparent intercalation of basalt and nummulitic limestone, subsequently found to be due to faulting.

Moreover, there is this strong reason for not using different names for the two varieties; the term "laterite" has been so generally applied to both forms of the rock by geologists, that it is no longer possible to

restrict it to one. When it becomes necessary, in the following pages, to distinguish between the two forms, they will be called "high-level" laterite and "low-level" laterite, these names, which merely refer to the position occupied by the two varieties on the highlands or near the coast, not involving any theory of the origin of the rock. Each will require separate notice, in order to explain its distribution and the theories proposed to account for its origin; but before proceeding to these questions, there is another form of ferruginous clay, very generally associated with laterite, which requires explanation.

Lithomarge.—Both forms of laterite frequently appear to pass into the underlying rock, whether this be igneous, metamorphic, or sedimentary. In the case of basalt, or gneiss underlying laterite, the upper part of the lower formation is decomposed, and forms a clay, which is impregnated with iron, by the water trickling through the laterite above, and becomes a kind of lithomarge, passing by insensible gradations into laterite itself. In fresh sections, where the detrital low-level form of laterite is the overlying rock, the limit of the two can usually be traced without difficulty, but surfaces which have been exposed for a length of time are generally covered with more or less of the limonite glaze and the lithomarge can no longer be distinguished from laterite.[1] This lithomarge is always more ferruginous above than below; it varies in colour from red through yellow to white, being usually mottled, and not unfrequently coloured purple or lilac in patches, and a few pipes often occur, produced apparently by the percolation of water.

Another form of lithomarge, found in many places, and especially to the northward, beneath the high-level laterite, and occasionally below the low-level form also, consists of hardened clay, sometimes sandy, and generally highly ferruginous, which shews no tendency to pass into the underlying rock, although it usually exhibits unmistakable transition into the laterite above. In these cases, the laterite and lithomarge together form a group of beds, superposed, as a rule unconformably, upon older rocks of various kinds. In some instances, as in Bundelkhand, this infra-lateritic formation contains pebbles,[2] and there is every reason for believing that it is a rock of sedimentary origin. The importance of this form of lithomarge, as a clue to the origin of laterite, will be seen in the sequel; for there is every probability in this case that the laterite is merely the lithomarge, altered by surface-action. In some cases, the present form of lithomarge contains hæmatite or limonite in

[1] Mem. G. S. I., I, p. 283, &c.
[2] Mem. G. S. I., II, p. 86.

considerable quantities,[1] sufficient to enable the mineral to be collected for iron ore, as in Bundelkhand, near Jabalpur, and on the eastern flanks of the Rájmahál hills.

Reconsolidation of laterite.—One peculiarity possessed, to an eminent degree, by all forms of laterite, is the property possessed by broken or detrital fragments of being recemented into a mass, closely resembling the original rock. Laterite itself has great powers of resisting atmospheric disintegration, being, in fact, produced by long action of the atmosphere upon various ferruginous clays; but the underlying formation, whether trap or gneiss, decomposes, and is slowly washed away, until the cap of laterite, originally horizontal, falls down, and becomes reconsolidated on the irregular surface, which it still covers. This is one way in which reconsolidation takes place; another is when broken fragments are washed down by rain and streams to a lower level, at which they become recemented.

Infertility.—The surface of the country composed of the more solid forms of laterite is usually very barren, the trees and shrubs growing upon it being thinly scattered and of small size. This infertility is perhaps due, in great part, to the rock being so porous that all water sinks into it, and sufficient moisture is not retained to support vegetation. The necessary result is, that laterite plateaus are usually bare of soil, and frequently almost bare of vegetation. Of course, this barrenness is by no means universal; soil sometimes accumulates on laterite caps, and some of the more gravelly or more argillaceous varieties support a moderate amount of vegetation. Still the general effect of the rock is to produce barrenness.

Distribution and mode of occurrence of high-level laterite.—The high-level laterite is chiefly developed on the Deccan plateau, and especially on the highest portions of the Sahyádri range, and the spurs running from the Gháts. It forms a cap on the uppermost traps exposed on the plateau, but it is also found at lower elevations, the lower beds being, however, as a rule, but of small extent or thickness. The summit bed, as it is termed by Mr. Foote, is not more than 50 to 90 feet in thickness in the Southern Máhratta country, and it is about the same at Mahábleshwar, but it is said to be from 100 to 200 feet thick at Bidar, north-west of Hyderábád. It occurs at varying heights above the sea, 4,700 feet at Mahábleshwar being probably the highest point, whilst at several places in the Southern Máhratta country it is found capping ridges and isolated hills from about 2,000 to nearly 3,500 feet above the sea, but it always overlies the highest lava flow in the country. At

[1] Mem. G. S. I., II, p. 81; XIII, p. 241.

Matheran, near Bombay, and on some neighbouring plateaus, there are caps of laterite at about 2,000 feet above the sea, but these do not belong to the summit bed, as the traps on the tops of these hills are not high in the series. Some of the laterite caps are very extensive; the bed at Bidar is said to be 28 miles long from west-north-west to east-south-east and 22 miles broad, and the area of laterite at Kaliani, 40 miles west of Bidar, is of even greater extent.[1]

The greater portion of the trap area in the Deccan has not been closely examined, but, so far as is known, laterite is of rare occurrence, except near the Western Gháts and in the Southern Máhratta country. A few very small caps are found south-west of Nágpúr, in South-East Berar, and probably similar small outliers occur here and there along the south-eastern margin of the volcanic region. Farther to the north-east, laterite occurs at Amarkantak, and on the eastern outliers of the Deccan traps, at Main Pat and Jumira Pat in Sirgúja, on the former being from 100 to 200 feet thick. North of the Narbada also, in Rewah, Bundelkhand, and in other States as far west as Guzerat, laterite is found, sometimes as much as 200 feet in thickness, capping outliers of the trap series.

In all the localities hitherto mentioned laterite occurs resting upon the Deccan traps, but not only does the high-level laterite overlap the traps, and rest upon older rocks, but it is found in places some hundreds of miles beyond any existing outlier of the volcanic series. Instances of this kind have been noticed by various observers in the Southern Máhratta country,[2] the same laterite bed being continued apparently, in some cases, from the trap surface on to the transition or metamorphic rocks,[3] whilst numerous outliers on the older formations are known to exist. Caps are said also to occur at high elevations on the Dambal or Kupputgode hills, east of Dharwar, and on hills in the neighbourhood of Bellary and Kadapa.[4] More to the north-east, in the high grounds of Patna, Kalahandi, Bastar, Jaipur, &c., between the Máhánadi and Godávari, caps of laterite, 50 to 100 feet thick, occur on many of the higher hills[5] at elevations of between 2,000 and 4,000 feet above the sea. The most eastern exposure known to occur in this neighbourhood is on the Kopilas hill about 2,050 feet above the sea, and 12 miles nearly due north of Cuttack.[6]

[1] Newbold: Jour. R. A. S., VIII, p. 228.

[2] Newbold: J. A. S. B., XIII, p. 996; J. R. A. S., VIII, p. 228; Foote: Mem. G. S. I., XII, pp. 205, 217, &c.

[3] Foote: l. c., pp. 205, 217.

[4] Newbold: J. R. A. S., VIII, p. 228.

[5] Ball: Rec. G. S. I., X, p. 169.

[6] The information of the occurrence of laterite on Kopilas hill was obtained by Mr. Ball from Dr. Stewart of Cuttack.

On the Chutia Nágpúr plateau to the northward, a great expanse of laterite is found, at elevations varying from 2,000 to 3,000 feet above the sea in several places, and especially to the north-west of Jashpur[1]; it differs, however, from the usual high-level laterite, in covering hills and valleys alike, and is probably, in part at least, a reconsolidated or secondary formation. Still, in places, it caps ridges and peaks in the usual manner. Leaving, for the moment, the Rájmahál hills, which require separate notice, a thick mass of laterite occurs on Moira hill, the highest peak of the Karakpur range, south of Monghyr, at an elevation of 1,500 feet. Turning thence westward, caps of the same rock are found, outside of the trap area, at several places in Bundelkhand,[2] and at two near Gwalior,[3] all on the highest ground of the country.

Besides the above-mentioned localities, there are some of the hills of Southern India where laterite has been reported to occur, but there is always a difficulty, unless the locality has been carefully examined, in determining the nature of the formation, since ferruginous clays, with but little of the true character of laterite, and due solely to the decomposition of gneissic rocks, have occasionally been described under the name. Such is certainly the case with the Nilgiris, one of the localities mentioned by several geologists. No well-authenticated occurrence of laterite is known at an elevation exceeding 5,000 feet above the sea.

Rajmahal Hills.—There is, however, a very important bed of this rock on the Rájmahál hills in Bengal.[4] These hills, like the highlands of the Bombay Deccan, are composed of bedded basaltic traps, and, as in the Deccan, the very highest bed consists of laterite; Mahuagarhi, the highest plateau in the range, 1,655 feet above the sea, being capped by this formation. The laterite in the Rájmahál hills is, in places, as much as 200 feet thick, and it slopes gradually from the western scarp of the hills, where it attains its highest elevation, to the Ganges plain on the east. Here too, as in the Deccan, there is, in places, an apparent passage from basalt into laterite, but the latter rock to the eastward is distinctly identical with the low-level laterite of Bengal, Orissa, and Southern India, and is clearly of detrital origin; whilst even at considerable elevations in the hills, fragments derived from the shales, which are interstratified with the basaltic flows, are found imbedded in the laterite, so that, as no distinct line has ever been drawn between the beds at different elevations, we appear in this case to have a passage from the high-level into the

[1] Ball: Rec. G. S. I., X, p. 170, note.
[2] Mem. G. S. I., II, p. 82.
[3] Hacket: Rec. G. S. I., III, p. 41.
[4] These hills have been described already; see p. 165. The laterite has been but briefly noticed; see Oldham: J. A. S. B, 1854, XXIII, p. 273; Ball: Mem. G. S. I., XIII, p. (222).

low-level laterite, and reasons for supposing that both were originally of sedimentary origin. The case, it should be remembered, is not clearly proved, the laterite of the Rájmahál country not having been specially examined with a view to test the connection between the beds to the eastward and those to the westward, but the two appear to be parts of the same formation,[1] and it is certain that both are, in this instance, detrital.

The evidence hitherto collected is insufficient to justify the conclusion, that the high-level laterite once formed a continuous bed, occupying the whole surface of the Indian Peninsula from the Ganges valley to the neighbourhood of Madras, but the manner in which caps now occur upon isolated peaks and ridges clearly shews that these caps formed part of a bed once much more extensive, and of which only a few remnants have been left undenuded. It is difficult, in presence of the great amount of denudation which has taken place since the laterite caps were part of a more or less continuous bed, to escape the conviction, that the high-level laterite must be of considerable geological antiquity.

Distribution, &c., of low-level laterite.—Before proceeding to discuss the very difficult subject of the origin of laterite, it will be best to point out the general distribution of the more sandy and typical variety found at low elevations, and especially in the neighbourhood of the coast. On the west coast of the Peninsula laterite has not been observed in the lowlands, or the Konkan, north of Bombay[2]; it appears, however, a little farther to the southward, between Bombay and Ratnagiri, and extends thence throughout large tracts of the low country intervening between the Sahyádri range and the sea, as far as Cape Comorin. It does not, of course, cover the whole surface; in many places it has been cut away by streams, so that the lower formations

[1] There is a possibility that the connexion between the high-level laterite of the Deccan and the low-level laterite of the eastern coast is not confined to the solitary instance of the Rájmahál hills, although no other case of passage can be traced which is equally well marked, and in some cases, as at Kopilas near Cuttack, the difference in level is very great; but, as will be seen, the low-level laterite of the eastern coast rises gradually from the neighbourhood of the sea, at a slope which, if continued inland, would connect the bed with the high-level formation. The latter is of much greater antiquity than the low-level bed, but the process of formation may have been continuous, the rock now found at a higher level being first formed, and that at a lower elevation being gradually consolidated, as the lower portion of the country was raised above the sea. It should be remembered that the higher part of the country, in all probability, was never depressed below the sea-level. This idea of the whole laterite being one continuous formation appears to have occurred to Newbold.—J. R. A. S., VIII, p. 240.

[2] Except near Surat, where the outcrops are of nummulitic age, or much older than the Konkan laterite in general. The rock differs from all superficial laterite, in being distinctly intercalated between other beds.

are exposed, and in parts of the country it appears to be wanting. The greater part of the region, however, has never been mapped geologically, and no details of the distribution of laterite are available, except in the country between Ratnagiri and Goa.

Here the rock appears to form a plateau, having a general elevation of 200 to 300 feet above the sea. On the coast it terminates in cliffs, the trap being exposed beneath it. The plateau extends for from 15 to 20 miles inland, and it is cut through by numerous rivers and streams, in all of which the trap is exposed, but at Ratnagiri, between the laterite and the traps, the lignite and clays are found, which were mentioned in the last chapter. Farther inland, the laterite is found at a higher elevation than near the coast, so that the rock appears to have a low slope towards the sea. The laterite is distinctly of detrital origin, and even conglomeratic in places; the thickness of the formation is considerable, but no exact measurements have been recorded, except at Ratnagiri, where it amounts to 35 feet, probably less than the average. It is evident that the plateau formerly extended much farther to the eastward, and it probably covered the whole of the country as far as the base of the Sahyádri range; for caps of laterite are found in places on the trap hills, and masses, reconsolidated from the detritus of the principal beds, are found at lower levels.

South of Malwán, the underlying rock is no longer trap, but gneiss, or some other metamorphic formation. The laterite appears to be similar to that of the Bombay Konkan. In Travancore, it overlies the fossiliferous tertiary beds, already mentioned.

On the east coast of India, laterite occurs almost everywhere, rising from beneath the alluvium, which fringes the coast, and sloping gradually upwards towards the interior, but this laterite is a much less massive formation, as a rule, than the rock of the western coast; it is seldom more than 20 feet in thickness, and it is often represented by a mere sandy or gravelly deposit, not more than 4 or 5 feet thick. Where it is thicker, the lower portion usually consists of lithomarge, produced by the alteration of the underlying rock. The laterite is frequently conglomeratic, and includes large, rounded, or subangular fragments of gneiss and other rocks; good instances being found at Trichinopoly, at many places near Madras, amongst which are the Red Hills, 7 miles to the north-west of the city, and around the detached hills north-west of Cuttack, in Orissa. In the Madras area, quartzite implements of human construction have been found in the laterite[1] in considerable numbers.

[1] For additional details of the laterite near Madras, see Mr. Foote's account, Mem. G. S. I., X, pp. 27-58.

The fringe of laterite is of very unequal width. In places, it forms a broad, low slope, stretching for many miles from the edge of the alluvium; in other places, it only remains as caps upon the older rocks. In one form or another, however, it appears to be traced, at short intervals, from Cape Comorin to Orissa, and thence northward, through Midnapur, Burdwan, and Birbhúm, to the flanks of the Rájmahál hills, where it is well developed, and where, as already noticed, it appears to pass into the high-level laterite.

The low-level laterite is not confined to the neighbourhood of the coast. It is found, frequently in patches, over many parts of the country, but these patches are rarely of large size, and they often appear to be due to local peculiarities, such as abundance of iron in the rocks, or reconsolidation of fragments derived from a bed of high-level laterite. Many such lateritic deposits are rather of the nature of ferruginous gravel than of true laterite. The small pisolitic nodules, so characteristic of some forms of laterite, are found abundantly in the older alluvium of the Ganges valley, and in many other superficial deposits in the plains of India; and wherever they are sufficiently abundant, they appear to become cemented with the accompanying sand and clay into a rock, closely resembling laterite in many of its peculiarities.

Theories of origin of high-level laterite.—Having thus stated, as briefly as is consistent with the object of affording a tolerably complete account of the rock, the distribution and mode of occurrence of the different varieties of laterite, the question of the manner in which this rock has been formed, in different parts of India, must next be considered. The subject has already been noticed as difficult, the difficulty arising from the fact that the rock has evidently undergone a considerable amount of change, both chemical and structural. The difference between laterite when first cut from the quarry underground and the same rock after exposure is well marked; the rock becomes harder, and the hardening appears not merely due to the desiccation of the argillaceous constituents, but also to a change taking place in the distribution of the peroxide of iron, the change being shewn by the colour becoming darker, and by the surface being covered with a glaze of limonite. Whether the anhydrous iron peroxide, which occurs in some forms of high-level laterite, becomes converted, by exposure, into hydrated peroxide, has not been ascertained; on this and other questions much light might be thrown by careful chemical analysis. But it is quite clear that the process of segregation of the iron has tended greatly to obscure any structure which may have existed originally in the rock, and that this segregative action is constantly in progress. It has already been stated

that iron is dissolved out of the laterite, and re-deposited in the underlying lithomarge, where the latter is merely an altered form of the rock beneath; and it is a common circumstance, in some forms of laterite, to find pisolitic nodules of hydrated iron peroxide, evidently due to segregation. These facts, and the process by which the surfaces of the rock, and of the tubes by which it is traversed, become coated with a glaze of limonite, render it evident that a transfer of iron oxide from one part of the rock to another is continually going on.

One view, which has been held by several good observers, and which has been strongly supported by Mr. Foote's examination of the laterite, or iron clay, in the Southern Máhratta country, is, that the high-level laterite is simply the result of the alteration *in situ* of various forms of rock, and especially of basalt, by the action of atmospheric changes.[1] Many of the dolerites of the Deccan contain iron in the form of magnetite, and large quantities of magnetic iron sand are found in the beds of streams, which flow over the traps, whilst bands, both of magnetite and hæmatite, are common locally in the metamorphic rocks. The gradual change from doleritic trap into laterite has been noticed by several observers,[2] and, so far as the Deccan alone is concerned, the evidence in favour of laterite being merely the result of atmospheric change, acting upon very ferruginous volcanic rocks, appears so strong, that, if there were no conflicting phenomena, it might be accepted as a satisfactory explanation. At the same time, there are some difficulties, to which attention was first called by Captain Newbold[3]; and although Mr. Foote[4] has shewn that they are not insuperable, still they should not be overlooked, because the apparently sedimentary origin of the rock in Bundelkhand and elsewhere tends to invalidate the conclusion, that the high-level laterite is merely the result of surface change.

The main argument, it should be remembered, in favour of supposing the high-level laterite of the Deccan to be merely altered dolerite is, that the two rocks are seen to pass into each other. This fact, which is unquestionably established, may be considered proof that laterite *may* result from the alteration of basalt, or a similar rock, but it is, of course, insufficient evidence to shew that such is the origin in all cases. It is always possible that the upper portion of the laterite is, in each case, of extraneous origin, and that the surface of the basalt beneath has been

[1] Some writers, of whom the best known is Dr. Carter, have supposed that the low-level laterite has originated in the same manner by the alteration *in situ* of basalt or other rocks, but in this case the detrital origin of the rock is unmistakable.

[2] Voysey: J. A. S. B., XIX, p. 274; Foote: Mem. G. S. I., XII, p. 202, &c.

[3] J. A. S. B., XIII, p. 995; Jour. Roy. As. Soc., VIII, p. 237.

[4] l. c., p. 203.

affected by the infiltration of iron, in the manner already described when explaining the origin of lithomarge. Numerous instances are found, on the other hand, in which the laterite rests upon the surface of basalt, which is either hard and unaltered, or soft and decomposed, without any appearance of a passage from one rock to the other. But this, again, is no proof that the laterite above the unaltered trap is not itself the result of alteration of a different lava flow; all that it shews is, that the non-lateritic rock beneath is not susceptible of the same change. It is clear that the evidence afforded by the circumstance that doleritic trap sometimes passes into laterite, and sometimes does not, is insufficient to decide the question, as to whether the latter is derived from the former, by a process of chemical alteration.

It has been stated that magnetite occurs in many of the Deccan dolerites, but, until far more analyses have been made, it is impossible to say whether any of these rocks contain as large a proportion of iron as the laterite. It is probable that some may, but it is certain that so large a proportion of iron as 15 or 20 per cent.[1] in any basalt is exceptional; yet this is not above the average amount in the Deccan laterite. At the same time, the larger percentage may, perhaps, be explained by a process of concentration, some of the other constituents of the rock having been removed in the process of change, but not the iron. There is, however, in opposition to this explanation, the fact, that the iron is evidently dissolved out of the laterite at present, since iron peroxide is re-deposited on the surface of pipes, &c., and in the underlying lithomarge.

One difficulty, to which especial attention was drawn by Captain Newbold, is the complete absence in the laterite of those nodules, large or small, of various forms of silica, such as agate, jasper, and crystalline quartz, so frequently found in the different forms of trap. It is difficult to understand, if laterite simply results from the alteration *in situ* of the Deccan dolerites, why no amygdaloidal structure, especially where the nodules contain so indestructible a mineral as agate, should be detected in the altered rock. Mr. Foote suggests[2] that, in the case of the summit bed, which appears to rest upon the highest traps, the absence of amygdaloidal structure may be due, in the first place, to the lava flow, now converted into laterite, having been of a peculiarly dense nature (and such dense beds do certainly occur in the Deccan traps, indeed they cannot be said to be rare, although they do not, as a rule,

[1] That is, of metallic iron; 15 per cent. of iron corresponds to 19·3 per cent. of protoxide, and 21·4 per cent. of sesquioxide.

[2] l. c., p. 203.

preserve their non-vesicular character over large areas); and secondly, to the fact that, being the uppermost flow, the water which percolated it did not contain silica in sufficient quantity to form siliceous nodules in the vesicular hollows. He also points out that the underlying bed, into which the summit bed laterite is seen to graduate in several sections, is a very argillaceous rock, without vesicular cavities or enclosed minerals.

One conclusion is clear. If the high-level laterite of the Deccan has been produced by the alteration *in situ* of volcanic rocks, only particular varieties of such rocks are capable of undergoing the alteration. If all were similarly liable to be converted into laterite at the surface, the occurrence of that rock would be more general, and less restricted to particular elevations. The great difficulty in the way of explaining the origin of the high-level laterite, so widely spread in Málwa and the Deccan, by a simple process of atmospheric alteration, is, in brief, that the hypothesis demands the occurrence, over an enormous area of country, of a volcanic rock (whether a tuff or a true lava flow is immaterial), of peculiar and unusual composition, containing a much larger proportion of iron than usual, and wanting the amygdaloidal structure, so common in the Deccan traps. This difficulty, it must be remembered, is, so far, only a reason for caution in coming to a conclusion; it does not shew that the hypothesis of alteration *in situ* is impossible.

The great extension of the laterite beyond the trap area may, of course, be explained, by supposing that the highest volcanic stratum covered a wider surface than any of the inferior lava flows; but in some cases, as in that of the Gauli plateau, south of Belgaum,[1] where a bed of laterite at a lower level than the summit bed was traced by Mr. Foote on both sides of the Mahádayi ravine, passing into the underlying trap to the northward and into metamorphic rocks to the south, this theory is untenable; and in this case, if the laterite be the result of alteration alone, the southern portion must have been formed from gneissic rocks. It is difficult to understand how two rocks, so totally dissimilar in constitution as dolerite and gneiss, can have produced precisely the same rock, by a simple process of disintegration *in situ.*

On the other hand, the difficulties in the way of supposing the high-level laterite to be sedimentary are considerable. The idea of its being a marine deposit can scarcely be entertained; there is not a shadow of evidence in any part of India to render it probable that the whole of the great trap plateau has been beneath the sea in tertiary times. It is inconceivable that fluviatile deposits should be so enormously extended, yet so thin. One objection, which at the first glance appears

[1] Mem. G. S. I., XII, p. 217.

important, is apparent rather than real. It is that a sedimentary deposit could not be formed on the highest portions of the country, because there could be no higher land in the neighbourhood, from which the sediment might be derived, whilst the singularly small amount of disturbance, which the Deccan rocks have undergone, renders it improbable that any great relative change of elevation has taken place. But it must be remembered that laterite is a rock which resists atmospheric action far more than most forms of doleritic trap; this is shewn by the manner in which hard, unaltered caps of laterite rest upon softened and decomposing basaltic rocks; and, consequently, the portions of the plateau, which were originally highest, if not capped by laterite, may have disintegrated more rapidly under atmospheric influences than those protected by the lateritic formation, until the latter remained forming the highest ridges, long after the unprotected portions had been swept away.

The evidence afforded by the laterite outliers in Bundelkhand[1] is distinctly opposed to the theory of alteration *in situ*. The whole group, laterite above, ferruginous clay, frequently containing sand and pebbles, below, is found indifferently capping trap and Vindhyan sandstones. Now, whatever may be the case with dolerite and gneissic rocks, no conceivable process of alteration could convert a purely quartzose sandstone, like the Vindhyan, containing a mere trace of iron, into an argillaceous rock, with 20 per cent. of iron entering into its composition; and the circumstance that the lower portion of the lateritic group is clearly detrital, proves that the laterite is not an altered outlier of the trap.

It appears almost impossible to separate the Bundelkhand laterite from the high-level laterite of the Deccan. Lithologically and stratigraphically the two rocks are identical. There can be no reasonable doubt that the trap once occupied the surface of the ground now cut out into valleys by the feeders and main streams of the Son, Narbada, and Máhánadi, and that Bundelkhand, with Málwa to the north, were united with Mandla and Sirgúja into one plateau of horizontal trap rocks. If this be conceded,—and it appears impossible to doubt it,—the caps of laterite near Saugor, occupying precisely the same relative position as those at Amarkantak and Main Pat, may fairly be considered part of the same bed; and the Rewah outliers, which are probably either beyond the original range of the trap, or else on ground which was above the general trap level, must be referred to the same origin. Now, the Amarkantak and Sirgúja laterites are not merely similar

[1] Mem. G. S. I., II, pp. 79-86.

in every respect to the other Deccan high-level outcrops of the rock, but they appear to be connected, by a series of small caps at intervals, with the typical formation of the Southern Máhratta country. There may be a break in the chain ; the distances are too great for any safe conclusions to be formed ; all that can be done is, to indicate the probabilities. It appears a fair inference that, if the Bundelkhand laterite is of aqueous origin, the rock of Amarkantak and the Deccan is the same.

The laterite of the Rájmahál hills is separated by so great a break from that of Sirgúja, and the Rájmahál traps are so much older than those of the Deccan, that it is impossible to say whether the Rájmahál laterite is of the same age as that of Central and Western India. Lithologically it is identical, and, like the Deccan laterite, it occurs, in part at least, at a considerable elevation, whilst its sedimentary origin has already been mentioned.

It will thus be seen that, despite all the observations which have been made on the high-level laterite of the Deccan in the course of the last fifty years, it is still impossible to say that this rock has been proved to be simply the result of atmospheric action on the traps and metamorphic rocks of the country, and it is equally unproved that it is due to sedimentary action. Before attempting to reconcile some of the difficulties, a few words may be devoted to the probable age of the formation.

Geological age.—The geological age of the high-level laterite must, of course, remain undetermined, until the mode of formation has been more definitely ascertained. If the rock be merely the result of surface alteration, it may be of any date subsequent to the termination of the volcanic outbursts; indeed, as has been justly pointed out by several observers, it must still be in process of formation. But, as its occurrence in the form of a few isolated caps shews that it was once a much more extensive formation, it must have existed before the denudation of the area, by streams, had much advanced; and, therefore, it must have formed, in part at least, soon after the termination of the volcanic eruptions. The great similarity between the high-level laterite and the beds of the same rock, interstratified with the nummulitic limestones and gravels of Guzerat and Cutch, tends to suggest the possibility, that the two are contemporaneous, and also that they may have been produced in the same manner, with, however, this important distinction, that the Guzerat beds are marine, whilst there does not appear to be any evidence in favour of supposing that the highlands of the Deccan were submerged during any portion of the tertiary period. Had they been submerged, the amount of denudation, which the traps must have undergone, would, in all probability, have caused the high-level laterite to be more distinctly

unconformable. At the same time, it is far from clear that the laterite is truly conformable to the highest trap flows. It has been hitherto assumed, rather than proved, that all the beds of laterite, at lower elevations than the summit bed, are of later age. Of course, on the theory of the laterite being merely an altered form of the traps, the occurrence of laterite, at various elevations, presents no difficulty; but if this rock be of any definite date, it is clear that extensive denudation must have reduced the level of such hills as Matheran, the uppermost beds of which are at least 2,000 or 3,000 feet below the highest volcanic flows, before the laterite was deposited. Nevertheless, the laterite of Matheran, although apparently non-detrital, may be a secondary product. This question of conformity to the highest traps requires, in fact, further investigation.

Possible hypothesis of origin.—The following hypothesis[1] may, perhaps, meet some of the difficulties above-mentioned; it is only suggested as a possible explanation, and by no means as a perfect theory. At the close of the Deccan trap period, the country must have been an immense plain, formed by the latest lava flows. But it has already been shewn that the quantity of volcanic ash, interstratified with the lava flows, increases amongst the upper and later flows, and it is highly probable that scoriæ and lapilli continued to be showered out, at intervals, after the outbursts of lava had ceased. Numerous cones, too, composed for the most part of ash beds, may have been left, so that an immense quantity of loose, incoherent materials must have been spread over the surface of the country. The laterite might, perhaps, be simply this loose ash, changed by chemical action; but, granting this view, it would be difficult to understand the detrital nature of such laterite beds as those described in Bundelkhand, and it is also not easy to account for masses, 200 feet thick, accumulating so far from the main volcanic vents, as to be beyond the area of the enormously extended lava flows. The quantity of iron, also, appears excessive. It is more probable that the laterite has been formed from the disintegrated tuffs and scoriæ, rearranged by the action of water. For a considerable period after the close of the volcanic eruptions, until the denuding action of water had established a system of river valleys, all rain falling on the surface of the country, and washing down the loose materials from a higher to a lower level, can have done little more than fill up hollows.

[1] This hypothesis was, to some extent, suggested in the late Sir C. Lyell's "Elements of Geology," 6th edition, 1865, p. 598. The rocks, however, to which Sir C. Lyell applied the term "laterite," differ materially from the Indian formation, and appear to be chiefly forms of bole. For some instructive remarks on the formation of ferruginous clays from volcanic detritus, see Phil. Trans., 1858, p. 711, already quoted in the chapter relating to the Deccan traps.

For, although the country must have been singularly level, still, as no fluid can run down an absolutely horizontal plane, the upper surfaces of the lava streams must have been slightly inclined, although the angle of inclination was very small. The presence of hollows is, indeed, proved by the previous existence of lakes. Possibly, the reason why high-level laterite is now found chiefly on the outskirts of the trappean area in the Southern Máhratta country, Mandla, Sirgúja, Bundelkhand, &c., is, that these tracts were rather lower in position than the main volcanic foci north of Bombay and in Eastern Guzerat. The peculiar circumstance, that the laterite now caps hills towering above the whole of the remaining country, is easily explained by the fact, already noticed, that laterite resists the disintegrating action of the atmosphere very much longer than any form of basaltic rock.

There is still a great difference between the composition of all scoriaceous volcanic tuffs and that of laterite, for which the above hypothesis fails to account. The fine ashes showered out from volcanoes are, however, easily decomposed, as is proved by the well-known fact of a few years sufficing to render such ashes fit to support a rich vegetation; and as it has been shewn that a decomposed basalt is easily converted into laterite, it is reasonable to suppose that volcanic scoriæ of similar composition to basalt are susceptible of the same change. But the quantity of iron still needs explanation. It is easy to suggest ferruginous springs, or fumeroles, from which crystals of specular iron might be deposited, as in the well-known cases around Vesuvius, but still one objection, already urged, against considering the laterite the result of simple alteration of one extensive lava flow, or ash-bed, remains; this is the difficulty of believing that the iron could have been so generally and equally distributed. It is not impossible that the scoriaceous accumulations, forming the cones of the old volcanoes and the loose ash-beds distributed over the country, were peculiarly ferruginous; and it is easy to understand, if the iron was in the state of either magnetite or specular iron, that it would resist disintegration longer than the felspathic and pyroxenic ingredients of the volcanic rocks, because it does so at the present time, and it is found unaltered in the streams, which wash away the detritus of disintegrated basalt. Another fact to be noticed is, that those deposits which contained less iron originally would be liable to remain unconsolidated, and would consequently be easily washed away, whilst the more ferruginous portions of the detritus would alone possess the power of being converted into hard, indestructible laterite.

One fact must on no account be overlooked. The laterites of the Guzerat nummulitics must, in all probability, have been formed of volcanic

detritus, washed down into the sea. They are only found amongst the very lowest tertiary beds, immediately above the traps, so that, as already suggested, they may have been contemporaneous with the high-level laterites. They are absolutely undistinguishable from the laterites of the Deccan. It is manifest that, whatever objection there may be to the acceptance of the view that the high-level laterites are formed from volcanic detritus, rearranged by water, it is certain that they may have been thus formed, and that the hypothesis involves no radical impossibility, because it is clear that the Guzerat laterites have originated in this manner.

There is, however, another objection to the hypothesis proposed, and it is at least as serious as the equal distribution of the iron. This is, that if laterite be formed from volcanic ashes, rearranged by water, why are no laterite beds found interstratified with the traps? It is unreasonable to suppose that loose materials were only washed down into the hollows and lower portions of the country after the close of the volcanic period, and not in the intervals between the lava flows. It is probable that the beds of bole, interstratified with the traps, are due to a similar process to that suggested for the origin of high-level laterite, but they are of comparatively small thickness or extent. Some of them, however, are highly ferruginous.

It will thus be seen that the suggestion above made, of the laterite being due to loose ash, rearranged by water, in the hollows left at the close of the volcanic outbursts, whilst satisfactorily explaining the mode of occurrence in a comparatively thin bed over wide areas, the absence of siliceous minerals, and the occasional intermixture of sand and pebbles, and whilst it is proved to be a possible theory by the fact that certain laterite beds must have been thus formed, fails to account, in an equally clear manner, for the universal distribution of so large a percentage of iron, or for the absence of lateritic beds interstratified with the traps, although these may be represented by the bands of red bole.

If the deposition of a thick bed of highly ferruginous clay be explained, the conversion of this clay into laterite appears to be due to the segregation of the iron either in a pisolitic form or as a cement binding the clay together. If the iron existed originally as magnetite, it has been peroxidized, and the peroxide has become more or less hydrated, the latter change taking place chiefly after exposure to the atmosphere. The pipes are not easily explained, nor is it at all clear why they are sometimes present and sometimes absent. They have been referred to the segregation of the iron in a tubular form and to the percolation of water, but they occasionally traverse parts of the rock which are not highly ferruginous, and in which they are not lined with

limonite; and although water may easily increase the size of the tube through which it passes, it is powerless to originate a channel, through solid rock, by percolation alone. The depth to which the tubes extend[1] appears too great to render it probable that they are due to roots of plants;[2] but, if once formed in this way, they might easily be kept open, and lined with a ferruginous glaze by the percolation of water.

When the formation of laterite beds has once been accounted for, the apparent change of lower beds into the laterite is evidently due to the decomposition of the underlying formation, and the infiltration of iron.

Beds at a lower level have, in all probability, been formed from the debris of the high-level laterite. It must be recollected that, in a formation like laterite, in which iron is irregularly distributed, the harder and heavier fragments, containing the greater portion of the iron, will be redeposited at no great distance by any transporting agency—as, for instance, rain-wash,—while the lighter and softer clays will be carried further. The highly ferruginous deposit, thus formed at a low level, would begin, as usual, to impregnate the decomposing rocks beneath it with iron, and to convert them into laterite.

Origin of low-level laterite.—This brings us to the subject of low-level laterite, as it appears along both coasts. It has already been explained that the rock forms a slope, with a very gentle inclination towards the sea; that it is clearly of detrital origin, and that it rests indifferently on various older rocks, metamorphic, gneiss, trap, or sandstone of various ages. Occasionally, as at Ratnagiri and near Cochin, sedimentary beds occur at the base of the laterite, and on the eastern coast laterite and gravel are interstratified, or pass into each other.

Some evidence will be given in the next chapter to shew that the slope on which the low-level laterite rests is, probably, a plane of marine denudation, formed when the coast lands were slowly emerging from the sea. The origin of the low-level laterite is, therefore, much more easily explained than that of the high-level formation. It may have been formed in places, as in the Konkan, south of Bombay, from the detritus of the high-level laterite; but one great difficulty in accounting for the origin of the latter—the presence of iron in large quantities—is easily explained, in the case of the low-level laterite, by the abundance of magnetic and specular iron sand, derived from the Deccan traps and the metamorphic rocks. The process by which an argillaceous deposit, rich in iron, is converted into laterite, must, of course, be the same as in the case of the high-level variety,

[1] Captain Newbold mentions one 30 feet in length at Bidar.

[2] There is a remarkable structural resemblance between some recent estuarine muds near Rangoon and laterite. In the mud, the tubes are due to roots, which decompose, and leave cylindrical pipes.

and the same effects have been produced by decomposition and infiltration of iron on the underlying rocks. The pisolitic nodules of brown hæmatite or limonite, so common in the low-level laterite and in various ancient alluvial deposits, probably derive their iron from the magnetite and specular iron sand.

There is one point on which a few words must be said, and that is the enquiry whether the low-level laterite is a marine formation. *A priori*, it would appear improbable that a marine formation should be deposited during the process by which a plane of marine denudation is elevated above the sea. On the other hand, the frequent occurrence of pebbles, often of large size, in the laterites of the east coast appears due to the action of the waves, especially where, as around isolated hills, which may originally have been islands, in Orissa, a mass of well-rounded shingle, in every way resembling a beach, is found cemented together by laterite. The absence of marine fossils may be due to their having been obliterated by the forces which produced the peculiar concretionary structure of the rock.

There are, however, two circumstances which appear to militate strongly against considering the laterite a marine formation. One of these is its remarkable thinness; throughout the east coast, so far as is known, it rarely exceeds 20 feet in depth; and the other is the very frequent occurrence in the Madras country of palæolithic implements embedded in the rock. Some of these might have been dropped into the sea from canoes, but it is incredible that the men who used the stones should have lost them in the sea in such numbers as would account for their present abundance.

On the whole, it appears most probable that the low-level laterite is a subaërial deposit, due however, in many cases, to the rearrangement of marine gravels and sands by rain and streams. All rain and stream action would tend to carry away the lighter sand and clay, and to leave behind the heavy iron sand; and to this may be due the concentration of the ferruginous element.

Age.—The presence of palæolithic human implements in the Madras laterite proves that the rock is of post-tertiary origin. The implements[1] found are chiefly of quartzite, and have evidently been fashioned from pebbles, derived originally from the rocks of the transition or Vindhyan series. It is probable that the laterite of the west coast may be of about the same age as that near the eastern shore of the Peninsula.

[1] For descriptions and figures, see Foote; Mad. Jour. Lit. Sci., October 1866, Ser. III, Pt. 2, p. 1; also Q. J. G. S., 1868, p. 484. One form is the same as that represented on Plate XXI of the present work, fig. 1.

Despite the geologically recent origin of the low-level laterite, the considerable amount of denudation which it has undergone shews that it is, in part at least, a formation of ancient date, counting by years. It has already been mentioned that, on the western coast, the plateau near the sea has been cut through by streams to a great depth, and the underlying trap exposed, and that farther inland, at a higher level, only a few caps of the low-level laterite remain. On the eastern coast, which, owing to the large amount of deposits brought down by rivers, is protected from the action of the sea, the laterite has undergone less denudation, in consequence of its being frequently covered by later alluvial deposits, but still, away from the coast, it has been removed by atmospheric action over large areas. It is probable that the land rose very slowly from the sea, the laterite forming on the raised slope, *pari passu* with the elevation, and that, consequently, the farther inland the rock, the older its date, and the longer the period during which it has undergone denudation from atmospheric agencies. But the deep ravines cut by the streams close to the western coast, near Ratnagiri, mark the lapse of a considerable period of time since the low-level laterite was first consolidated, and a curious piece of evidence of the same kind has been recorded by Mr. Foote[1] in the neighbourhood of Madras.

Between two villages called Amerumbode and Maderapaucum, east of Sattavedu, and about 30 miles north-west by north of Madras, are some stone circles, made of blocks of the laterite, in which, in the immediate neighbourhood, palæolithic implements are found in abundance. The stone circles are known in the country as "Karambar rings," and precisely similar rings of stone are found in many parts of India, associated with various other rude stone buildings, such as kistvaens and cromlechs. That these stone circles are of much later date than the palæolithic implements is evident—first, because the circles are, in the particular case near Madras, constructed of rock in which the implements are embedded; secondly, because iron implements, which mark a far more advanced stage of human progress, have been repeatedly found within the enclosures; but, nevertheless, the stone circles themselves must be the work of a very ancient period, for all record of their construction, or even of the people who built them, has passed away. It will be shewn in the next chapter that the palæolithic age of India is, probably, of great antiquity, man having been, in all probability, contemporaneous with many animals now extinct, or replaced by different forms.

[1] Mem. G. S. I., X, p. 47.

CHAPTER XVI.

PENINSULAR AREA (THE INDO-GANGETIC PLAIN INCLUDED).

POST-TERTIARY AND RECENT FORMATIONS.

Extent — Distinction from tertiary beds — Relations to later tertiary rocks in Himalaya, Punjab, and Sind — Evidence of glacial epoch — Fauna and flora of Indian mountains — Post-tertiary changes of level in the Indian Peninsula — Hypothetical marine origin of Sahyádri scarp — Depression of land in the deltas of the Indus and Ganges — Lonar Lake — Various forms of post-tertiary deposits — Cave deposits — Kankar — — Older river gravels and clays — Alluvial plains of Narbada, Tapti, &c. — Old alluvium of Narbada — Palæontology — Fluviatile origin of Narbada alluvium — Tapti and Purna alluvial plains — Older alluvial deposits of Godávari — Krishna valley.

Extent.—Although the post-tertiary (post pliocene or quaternary) and recent formations of India occupy an immense area, their geological interest and importance are comparatively small. They form the wide plains of the Indus, Ganges, and Brahmaputra, and cover large tracts of country south of the Gangetic, and east of the Indus plain. No older formation is exposed throughout the greater portion of the belt of alluvial low land fringing the eastern coast of the Peninsula, and sub-recent accumulations occupy a large area in Guzerat and in some other districts near the western coast. Large deposits in the valleys of the Peninsular rivers and upon the fertile plains of the interior are also of recent or sub-recent origin.

Distinction from tertiary beds.—In India it is very difficult to draw a clear and distinct line between tertiary and post-tertiary formations. The limit of the two in Europe coincides with the glacial epoch, but as no physical trace of this cold period has hitherto been detected in Peninsular India, the distinction between the pliocene tertiary formations and the post-pliocene beds is less easily defined. Practically, no difficulty has hitherto arisen, because the tertiary beds of the Peninsula are comparatively unimportant, and those which occur belong apparently to the older or middle tertiaries, and not to the newer beds, so that there is a marked break between the tertiary and post-tertiary deposits; but some doubt attaches to the relative position of the most recent rocks in Kattywar. Hitherto, throughout Peninsular India, except in the neighbourhood of the sea coast, all post-tertiary deposits known are

of fresh-water origin,[1] and all the unconsolidated and undisturbed deposits of the river valleys are classed in this division. Amongst the older valley deposits, as in the post-pliocene rocks of Europe, bones of extinct mammals are found together with recent forms of fresh-water and terrestrial mollusca, whilst the newer gravels, sand and clay contain only the remains of mammalian species identical with those now inhabiting the country. There is some possibility that, amongst the fossiliferous gravels of the Indian river valleys, beds of older age than post-pliocene may occur, but hitherto no fossils of undoubted tertiary date have been discovered in the superficial deposits, although some forms differ so widely from living species as to suggest the existence of older beds. The works of man have now been found in two instances in Indian post-pliocene beds, but no human remains have hitherto been detected in older formations. These remarks, however, apply solely to India; in Burma, as will be shewn hereafter, tertiary mammals are found in the beds of the river valleys.

Relations to tertiaries of Himalaya, Punjab, and Sind.—South of the great Indo-Gangetic plain, the post-tertiary deposits rest upon old formations, all of pre-tertiary date, but to the north and west of the plain, at the base of the Himalayas, and on the flanks of the hill ranges in Sind and the Punjab, as well as throughout the valley of Assam, later tertiary rocks immediately underlie the post-tertiary beds. There is, in these cases, a marked distinction between the two, the pliocene tertiaries of the Siwalik formation being greatly disturbed, and evidently older than the last great changes in the relative levels of the Himalayan region, Afghanistan and Baluchistan, whilst the modern alluvial deposits preserve their original horizontality. But even in this case the difficulty, already noticed, of drawing a definite line between the tertiary and the later beds is exemplified, for, in the uppermost beds of the Siwalik series, some mammalia are represented, of which the bones are also found in the older valley deposits of the Peninsula. The difficulty increases on passing into the Irawadi valley in Burma, where beds, apparently representing the disturbed Siwalik rocks and containing the same species of mammals, are found horizontal and unconsolidated immediately beneath the sub-recent valley deposits.

Evidence of glacial epoch.—It has already been stated that there is, in Peninsular India, so far as is known, no physical evidence of a geologically recent cold epoch, and some European geologists appear to

[1] It will be shewn presently that the opinion held by some observers, that the older alluvial deposits of the Gangetic plain are marine, is unsupported by evidence.

doubt whether India was affected by the glacial period. There is in the Himalayas abundant and unmistakable evidence of a great extension of the glaciers at no very distant geological date, ancient moraines being found in many valleys of Sikkim and Eastern Nepal at elevations of between 7,000 and 8,000 feet,[1] and distinct traces of glacial action exist in valleys the lowest portion of which is not now more than 5,000 feet[2] above the sea. Moraines have been noticed by Colonel Godwin-Austen[3] farther east in the Nága hills, south of the Assam valley, as low as 5,000 feet; in the Western Himalayas, perched blocks are found 3,000 feet above the sea,[4] and very large erratics have recently been noticed in the Upper Punjab at much lower elevations.[5] It has, however, been suggested that the Himalayas, although they are still the loftiest mountains in the world, may have been depressed 8,000 feet since the period when the glaciers reached their maximum extension,[6] and the supposed erratics of the Western Himalaya and Punjab have been referred to river action.[7] The explanation in both cases appears quite inadequate by itself, unless the temperature was much lower than at present; still, it is of much importance to ascertain whether any collateral evidence is procurable of a cold period in India in later tertiary or post-tertiary times, it being remembered that a general refrigeration of the earth's surface, sufficient to produce an arctic climate in Central Europe, would not diminish the temperature of the Indian Peninsula below the average of the temperate zone at the present time.

It is true that no proof of the former existence of glaciers on the hills of Southern India has ever been detected, but this is important so far as negative evidence can be trusted, because it accords with the general absence, throughout the Peninsula of India, of any indication of depression on a large scale in recent geological times, and with the probability of the peninsular area having lately undergone a slow elevatory movement. The fact, however, that the hills of Southern India are probably higher, certainly not lower, than they were in late geological times, lends much force to the argument, derived from the animals and plants inhabiting them, in favour of a lower temperature having existed at a comparatively recent geological period.

[1] Hooker's Himalayan Journals, II, p. 7, &c.
[2] J. A. S. B., 1871, XL, Pt. 2, p. 393.
[3] J. A. S. B., 1875, XLIV, Pt. 2, p. 209.
[4] Mem. G. S. I., III, Pt. 2, p. 155.
[5] By Messrs. Theobald and Wynne, Rec. G. S. I., VII, p. 86, X, pp. 123, 140; Mem. G. S. I., XIV, p. 116.
[6] Mem. G. S. I., III, Pt. 2, p. 156.
[7] J. A. S. B., 1877, XLVI, Pt. 2, p. 1.

Fauna and flora of Indian mountains.—This argument is, briefly, the following. On several isolated hill ranges, such as the Nilgiri (Neilgherry), Animalé (Animullay), Shivarai (Shevroys), and other isolated plateaus in Southern India, and on the mountains of Ceylon, there is found a temperate fauna and flora, which does not exist in the low plains of Southern India, but which is closely allied to the temperate fauna and flora of the Himalayas, the Assam range (Garo, Khási, and Nágá hills), the mountains of the Malay Peninsula and Java. Even on isolated peaks, such as Parasnáth, 4,500 feet high, in Behar, and on Mount Abu in the Arvali (Aravelli) range, Rajpútána, several Himalayan plants exist. It would take up too much space to enter into details: the occurrence of a Himalayan plant like *Rhododendron arboreum*, and of a Himalayan mammal like *Martes flavigula* on both the Nilgiris and Ceylon mountains will serve as an example of a considerable number of less easily recognised species. In some cases there is a closer resemblance between the temperate forms found on the peninsular hills and those on the Assam range[1] than between the former and Himalayan species, but there are also connections between the Himalayan and peninsular temperate regions which do not extend to the eastern hills. The most remarkable of these is the occurrence on the Nilgiri and Animalé ranges and on some hills further south. of a species of wild goat, *Capra hylocrius*, belonging to a sub-genus (*Hemitragus*), of which the only other known species, *C. jemlaica*, inhabits the temperate region of the Himalayas from Kashmir to Bhútán. This case is remarkable, because the only other wild goat found completely outside the Palæarctic region is another isolated form on the mountains of Abyssinia.[2]

The range in elevation of the temperate fauna and flora of the Oriental region in general appears to depend more on humidity than temperature, many of the forms, which, in the Indian hills, are peculiar to the higher ranges, being found represented by allied species at lower elevations in the damp Malay Peninsula and Archipelago, and some of

[1] Only one species of plant, however, is mentioned by Hooker and Thomson (Introductory Essay to the Flora Indica, p. 238) as being found both in the Khási hills and Nilgiris, but not in the Himalayas. One land shell at least, *Bulimus nilagaricus*, has the same distribution, and the genus *Streptaxis* is found in Burma, the Khási hills, and the Southern Indian ranges, but not in the Himalaya west of Bhútán. Several other instances might be quoted.

[2] A still more extraordinary case, if confirmed, would be the occurrence of a snake belonging to the Palæarctic genus *Halys* on the hills of Southern India, but the affinities of *Trigonocephalus ellioti* are still doubtful, the species not having been discovered by later observers. The importance of the occurrence of a wild goat on the hills of Southern India is slightly diminished by Mr. Lydekker's discovery of extinct species in the Siwaliks and in the upper tertiary beds of Perim Island.

the hill forms being even found in the damp forests of the Malabar coast. The animals inhabiting the Peninsular and Cylonese hills belong, for the most part, to species distinct from those found in the Himalaya and Assam ranges, &c.; in some cases even genera are peculiar to the hills of Ceylon and Southern India, and one family of snakes is unrepresented elsewhere. There are, however, numerous plants and a few animals inhabiting the hills of Southern India and Ceylon which are identical with Himalayan and Assamese hill forms, but which are unknown throughout the plains of India.

That a great portion of the temperate fauna and flora of the Southern Indian hills has inhabited the country from a much more distant epoch than the glacial period may be considered as almost certain, there being so many peculiar forms. It is possible that the species common to Ceylon, the Nilgiris, and the Himalayas may have migrated at a time when the country was damper, without the temperature being lower, but it is difficult to understand how the plains of India can have enjoyed a damper climate without either depression, which would have caused a large portion of the country to be covered by sea, a diminished temperature which would check evaporation, or a change in the prevailing winds. The depression may have taken place, but the migration of animals and plants from the Himalayas to Ceylon would have been prevented, not aided, by the southern area being isolated by sea, so that it may be safely inferred that the period of migration and the period of depression were not contemporaneous. A change in the prevailing winds is improbable so long as the present distribution of land and water exists, and the only remaining theory to account for the existence of the same species of animals and plants on the Himalayas and the hills of Southern India is depression of temperature.[1]

Post-tertiary changes of level in the Indian Peninsula.—In the preceding discussion of changes probably caused by the glacial period, and also in the chapter on laterite, a recent rise of the Indian Peninsula was mentioned. It will be useful, before describing the post-tertiary formations, to state the evidence on which the belief in a recent rise of land is founded.

[1] The above is a meagre and condensed account of a very interesting subject, which requires further enquiry. One possible objection may be answered at once. It is true that many of the temperate damp-loving forms of the Nilgiris and Ceylon hills are forest forms, and it may be urged that they might have migrated when the plains of India were covered with forest. But, judging from what remains of the forest on the plains of the Carnatic, Deccan, Central Provinces, &c., the flora even when the whole was forest differed so widely from that of the hills, that it is improbable that any general diffusion of hill species could have taken place without a change of climate.

In a subsequent chapter, reference will be made to the probable influence of the glacial epoch on the Siwalik mammalian fauna.

In the chapters of this work relating to the Himalaya, the Punjab, and Sind, it will be shewn that great disturbances and important changes have taken place since the close of the pliocene epoch. In all the countries mentioned, rocks containing the remains of later tertiary mammalia are found dipping at high angles and not unfrequently vertical, and although, in the Himalayas, there is evidence of great disturbance at an earlier period, it appears probable that the older tertiary rocks in Sind have been chiefly, if not entirely, upheaved since the deposition of the pliocene beds. In Baluchistan also pliocene strata are found greatly disturbed, but the direction of the folds into which the strata appear to have been thrown is at right angles to the strike of the anticlinal and synclinal axes in Sind.

There is no clear evidence that any portion of the Peninsula of India was affected by the disturbances to which the elevation of the Himalayas and of the Sulemán and Khirthar ranges in the Punjab and Sind is due. But it is scarcely credible that, whilst such enormous changes were taking place in neighbouring areas, no alteration of level should have ensued in the Peninsula. In the sea to the south-west, the presence of the Maldive, Laccadive, and Chagos groups of atolls and coral reefs points to slow depression, and there is unmistakable proof of a recent sinking of the land on the Arabian coast near the mouth of the Persian Gulf.[1] On the coasts of India, except in the Gangetic delta, however, no distinct evidence of recent depression has been noticed,[2] whilst at several points contrary indications have been detected.

Commencing on the eastern coast of India, the first thing to be noticed is, that the low-level laterite is deposited on a gentle slope of older rocks, such as is formed by the sea, and known as a plane of marine denudation. It is true that this slope has been much broken up and denuded in places, so that the period of its elevation may be old, counting by years, but the fact that the laterite rests upon a surface of the older rocks, unaffected by subaërial action, shews that the period of elevation and the formation of the laterite were either contemporaneous, or separated by a brief interval of time, and the post-tertiary date of the laterite is proved by the presence of human implements.

Around some of the hills, also, as already noticed in the remarks on laterite, rounded pebbles, apparently belonging to an old sea beach, are found cemented by laterite. This is at an elevation of probably not less than 100 to 200 feet above the present sea-level. Nearer to the sea,

[1] Rec. G. S. I., V, p. 76.

[2] For instances of encroachment by the sea on the coast, see Newbold, Jour. R. A. S., VIII, pp. 250, 252, &c., and King and Foote, Mem. G. S. I., IV, p. (362). The destruction mentioned is, however, solely due, so far as is known, to the ordinary action of the waves, and no depression of land has been shewn to take place.

beds of marine or estuarine shells have been found both in Orissa and near Madras, at a height of several feet above the sea, and at a considerable distance inland. Further details of these beds will be given on a subsequent page. On the coast of Orissa, parallel ranges of sand-hills appear to mark old shore lines; the tide is said formerly to have come farther up the rivers[1] than it does now, whilst the Black Pagoda near Puri (Pooree), originally said to have been built on the sea-shore, is now more than a mile distant inland.[2] In the extreme south of India, near Ramnad, sandstones occur, some of which form Adam's Bridge between the Peninsula and Ceylon; and it is stated by Newbold[3] that these beds contain recent marine shells, and must have been raised from the sea at no distant date. It, however, remains to be seen whether the rocks are not of tertiary age, like the Cuddalore sandstones.

Passing onwards to the west coast, the low-level laterite is again found resting on a slope of the older rocks, and this slope again presents the characters of an ancient plane of marine denudation. The laterite in the Bombay Konkan, near the coast, appears to be raised to a greater height above the sea than on the opposite shore of the Peninsula; this may be due to the much greater destruction of the west coast by the sea, and to the circumstance that the newer laterite at the lowest level has been swept away; the force of the sea on this coast being increased by the strong south-west monsoon, whilst the defence afforded by river deposits on the east coast is in a great measure wanting on the western. But it is also probable that more elevation has taken place to the westward, and some further evidence to this effect will be mentioned, in reference to the alluvial deposits of the rivers Narbada and Tapti. At Bombay recent marine shells are found, forming the flat on which part of the city is built, several feet above high-water mark. In Kattywar, especially near Porbandar, dead oysters were found by Mr. Theobald in the creeks at several places far above the present range of the tide, and at Patan, barnacles and *serpulæ* were observed on the foundation of an old temple, now only wetted by the highest floods. In Sind, a number of oysters have been noticed attached to a low cliff at least 10 feet above high-water mark close to Cape Monze.[4] In the case of Kattywar and Sind, however, the elevation may be very recent, and these countries are beyond the true peninsular limits.

Hypothetical marine origin of Sahyadri scarp.—The escarpment of the Sahyádri range, a remarkable feature of the hills parallel

[1] Mem. G. S. I., I, p. 276.

[2] For many native traditions of a rise of land both on the Coromandel and Malabar coasts, see Newbold, Jour. R. A. S., VIII, p. 250, &c.

[3] l. c., p. 243.

[4] MS. reports; see also Rec. G. S. I., V, p. 111.

to the western coast of the Peninsula, has frequently been noticed as furnishing evidence of a rise of land. Throughout the trap country of the Bombay Presidency, the Western Gháts rise from the Konkan in an almost unbroken wall, varying in height from 2,000 to 4,000 feet, cut back in places by streams, projecting here and there into long promontories, but preserving throughout a singular resemblance to sea cliffs. This resemblance, however, ceases to a great extent to the southward, where the metamorphic rocks replace the horizontal basaltic traps. The escarpments of the Málwa plateau, north of the Narbada, and of the Deccan plateau south of Khándesh, although far inferior in elevation to the scarp of the Sahyádri, resemble the latter too closely in appearance to justify the assumption, without further evidence, that the cliffs of the Western Gháts are of marine origin. The parallelism of the Sahyádri escarpment to the sea-coast is suggestive of a connexion between the two, and this connexion is strengthened by the facts that a thickness of at least 4,000 feet of bedded trap has been removed from the surface of the Bombay Konkan, and that the plane of marine denudation already mentioned as supporting the low-level laterite extends in places nearly to the foot of the scarp. The circumstance that the hills of the Sahyádri are inhabited by certain fresh-water mollusca belonging to the genus *Cremnoconchus*, which is unknown elsewhere, and which is so closely allied to Indian forms of the littoral marine genus *Littorina* as to render it probable that both are descended from the same ancestors, also tends to strengthen the view that the Sahyádri mountains were formerly washed by the sea. But it is certain that great denudation has taken place since the scarp was a sea cliff, and it is far from improbable, even if the sea once extended to the base of the Western Gháts, that the epoch belonged rather to tertiary than post-tertiary times. It is also possible that the isolation of the different hill ranges of Southern India, such as the Shivarai, and the denudation of the Pálghát Gap south of the Nilgiri plateau, are due in part to ancient marine action of the same date as the formation of the Sahyádri escarpment. In this case, as in so many others connected with Indian geology, all that is now possible is to suggest probable interpretations of phenomena, and to leave them for future exploration to confirm or contradict.

Depression of land in deltas of Indus and Ganges.—But whilst throughout the rock area of the Indian Peninsula there are numerous proofs of an elevation of land during late geological epochs, the evidence of depression is equally marked in the delta of the Ganges, and probably in that of the Indus. The details of the Calcutta bore-hole will be given in a subsequent page, and they alone suffice to prove that the ground in the neighbourhood of the Hooghly must have

been depressed at least 480 feet in comparatively recent times. There are also other circumstances connected with the physical geography of the delta which point to the probability of considerable sinking having taken place. In the delta of the Indus the evidence is less clear, and the only known cases of depression are those said to have coincided with the earthquakes of 1819 and 1845. Both east of the Indus delta, in Kattywar, and to the westward near Cape Monze in Sind, there is, as already noticed, evidence of a recent rise of land, and it is probable that the lower portion of the Indus plain, with the Ran of Cutch and other tracts in the neighbourhood, have only, in recent geological times, been converted into land, as will be shewn when describing the delta.

Volcanic eruptions in Bay of Bengal.—It must not be forgotten that the great belt of volcanoes which extends throughout the Malay Islands, Java, Sumatra, &c., is supposed to terminate in Barren Island in the eastern portion of the Bay of Bengal, at a considerable distance from the coast of the Indian Peninsula. The belt of volcanoes should perhaps rather be considered as terminating at Narcondam than at Barren Island. By many writers it has been suggested that the mud volcanoes of Cheduba and Rámri on the coast of Arakan are a northern continuation of the Malay volcanic chain, but this is improbable, despite various accounts of eruptions and upheaval of land, because there is no known connection between the so-called "mud-volcanoes" and true volcanic action.[1] A distinctly volcanic outburst, accompanied by showers of pumice and ashes, is said to have taken place in the sea off Pondicherry in 1756,[2] and to have formed a shoal which subsequently disappeared, but the description, as in the case of the Cheduba eruptions, contains some elements of doubt.

Lonar Lake.—This is, perhaps, the best place to notice a very curious crateriform lake[3] situated in the interior of the Indian Peninsula, near the village of Lonar, about 40 miles east by north of Jálna, in the northern part of the Nizam's territory, and about half way between Bombay and Nágpúr. The surrounding country for hundreds of miles consists entirely of Deccan trap; in this rock, at Lonar, there is a nearly circular hollow about 300 to 400 feet deep, and rather more than a mile in diameter, containing at the bottom a shallow lake of salt water without any outlet. This water deposits crystals of sesquicarbonate of soda according

[1] For a full account of these supposed eruptions, see Buist, Ed. New Phil. Jour., 1852, LII, p. 342. The mud-volcanoes of Rámri will be further noticed in the chapter on Burma.

[2] J. A. S. B., 1847 XVI, p. 499.

[3] Malcolmson, Trans. Geol. Soc., Ser. 2, V, p. 562; Newbold, Jour. Roy. As. Soc., IX, p. 40 (with this paper there is a fairly executed view of the lake); G. Smith, Mad. Jour. Lit. Sci., XVII, p. 1. See also Rec. G. S. I., Vol. I, p. 63, where other references are given.

to Malcolmson, who analysed them. The sides of the hollow to the north and north-east are absolutely level with the surrounding country, whilst in all other directions there is a raised rim, never exceeding 100 feet in height, and frequently only 40 or 50, composed of blocks of basalt, irregularly piled, and precisely similar to the rock exposed on the sides of the hollow. The dip of the surrounding traps is away from the hollow, but very low.

It is impossible to ascribe this hollow to any other cause than volcanic explosion; no such excavation could be produced by any known form of aqueous denudation, and the raised rim of loose blocks around the edge appears to preclude the idea of a simple depression. It is true that there is no sign of any eruption having accompanied the formation of the crater; no dyke can be traced in the surrounding rocks; no lava or scoriæ of later age than the Deccan trap period can be found in the neighbourhood. The raised rim is very small, and cannot contain a thousandth part of the rock ejected from the crater; but it is impossible to say how much was reduced to fine powder, scattered to a distance, or removed by denudation.

Assuming that this extraordinary hollow is due to volcanic explosions, the date of its origin still remains to be determined. That this is long posterior to the epoch of the Deccan traps is manifest; for the hollow appears to have been made in the present surface of the country, carved out by ages of denudation from the old cretaceous lava flows. To all appearance, the Lonar lake crater is of comparatively recent origin; and if so, it proves that in one isolated spot in India, a singularly violent explosive action must have taken place, unaccompanied by the eruption of melted rock. Nothing similar is known to occur elsewhere in the Indian Peninsula.

Various forms of post-tertiary deposits.—The following are the most important post-tertiary formations in Peninsular India, the newest being placed first. The Indo-Gangetic plain will be treated in the present chapter as a portion of the Peninsula.

1. Blown sand.
2. Soils, including black soil or regur.
3. Modern alluvial deposits of rivers and deltas.
4. Raised littoral accumulations of shells, sand, &c.
5. Alluvium of the Coromandel coast, Guzerat, Cutch, &c.
6. Coast laterite.
7. Older alluvial river deposits.
   - Alluvium of Indo-Gangetic plain.
   - Narbada gravels.
   - Godávari gravels and other older river deposits.
8. Cave deposits.

It will, however, not be convenient to treat of these deposits precisely in the order mentioned, which coincides, so far as is known, with the probable geological succession of the various beds. The newer and the older forms of alluvial deposits are in many parts of India so closely connected with each other, and so difficult to distinguish, that they must be discussed together. The coast laterite has been already described in the last chapter.

Cave deposits.—There is only one locality in the Indian Peninsula at which mammaliferous cave deposits have been detected. This is at a place called Billa Súrgám,[1] a few miles north of Bánaganpilí, in the Karnúl district. The caves are in limestone belonging to the Karnúl transition series; the interior of the hollows examined is encrusted with stalagmite, and, beneath a floor of this substance, a red indurated marl is found, abounding in bones of mammals, large and small. The bones of the smaller animals are said to occur in large quantities. A collection made by Captain Newbold, who discovered the caves, was presented to the Asiatic Society of Bengal, but no description of the bones was ever published, nor can the specimens be found at present. A larger and more perfect collection was retained by Captain Newbold for examination in Europe, but no account of it appears ever to have been published. During the period of more than thirty years which has elapsed since attention was called to the locality by Captain Newbold, the spot appears to have been forgotten, and we are still ignorant of the value of the mammalian remains preserved.[2]

Kankar (kunkur).—Before proceeding further, a few words are requisite in explanation of a word which it will be found necessary to use occasionally in the following pages. To Anglo-Indians it is quite unnecessary to explain the meaning of the term *kankar*, but the explanation may be of some use to European students. The original signification of the word is gravel, the term being applied to any small fragments of rock, whether rounded or not. By Anglo-Indians, however, the name has been especially used for concretionary carbonate of lime, usually occurring in nodules, in the alluvial deposits of the country, and especially in the older of these formations. The commonest form consists of small nodules of irregular shape, from half an inch to three or four inches in diameter, and composed within of tolerably compact carbonate of lime and externally of a

[1] A description by Captain Newbold, the discoverer, is given; J. A. S. B., XIII, 1844, p. 610.

[2] It is proposed by the Geological Survey to re-examine the locality as soon as possible.

mixture of carbonate of lime and clay.[1] The more massive forms are a variety of calcareous tufa, which sometimes forms thick beds in the alluvium, and frequently fills cracks in the alluvial deposits, or in older rocks.[2] In the beds of streams immense masses of calcareous tufa are often found forming the matrix of a conglomerate, of which the pebbles are derived from the rocks brought down by the stream. There can be no doubt that the kankar nodules, calcareous beds, and veins are all deposited from water containing in solution carbonate of lime, derived either from the older rocks of various kinds, or else from fragments of limestone and other calcareous formations contained in the alluvium.

Older river gravels and clays.—The older alluvial deposits of the Indian rivers comprise a large portion of the enormously thick clays, gravels, &c., of the great plains of Northern India, and they are also well represented in the valleys of the Peninsula. Leaving for the moment the description of the Indo-Gangetic plain, the various older alluvial deposits of the peninsular rivers deserve notice, both on account of the area occupied and of the organic remains they have yielded. The rivers of the Peninsula may be divided into two groups; the first, comprising the Narbada and Tapti, which flow westward, draining the central portion of the peninsula, and the second including the Máhánadi, Godávari, Krishna, Pennar, Káveri, and several minor streams flowing eastward into the Bay of Bengal. A third group might be composed of the southern affluents of the Ganges, the Chambal, Son, &c., whilst some streams of Rajpútána and Guzerat, of which the most important are the Máhi and Lúni might be classed with the Narbada and Tapti, but none, except the two last named, are known to contain old alluvial deposits of any importance.

[1] The following analyses will give a fair idea of the usual composition of nodular kankar:—

	1		2	3	4		5	6	7	8	9
Carbonate of lime ...	72·	...	72·	56·94	78·5	...	54·	65·4	66·3	57·18	79·33
Carbonate of magnesia	0·4	...	1·30	1·72	2·	...	...	...	...	...	...
Silica	15·2	Oxide of iron .	·70	1·67	2·	Oxide of iron and alumina . .	2·7	1·9	2·	10·32	6·73
Water . . .	1·4	Clay .	22·	30·	10·50	Water and organic matter . . .	2·7	2·3	4·5		
Oxide of iron and alumina . . .	11·0	Sand . .	2·	9·67	7·	Insoluble . .	40·6	30·4	27·2	32·50	13·94

1, Ghazipur, Prinsep, Gleanings in Science, III, p. 278; 2, 3, 4, Rániganj, Dejoux; Rec. G. S. I., VII, p. 123; 5, Barmuri; 6, Ramnagar; 7, Sanktoria, all near Rániganj, Tween, ibid.; 8, 9, Saháranpur, Thomson, Rurki Treatise, Civil Engineering, I, p. 115.

[2] See the account by Captain E. Smith of the kankar in the Jumna alluvium, J. A. S. B., II, p. 622; also Newbold, J. R. A. S., VIII, p. 258.

Alluvial plains of Narbada, Tapti, &c.—In dealing with the two groups first named, one striking peculiarity deserves notice. Extensive alluvial plains, composed of clays and gravels, exist in the valleys of the Narbada and Tapti. In the Narbada valley, the principal plain extends from a little east of Jabalpur to Harda, a distance of more than 200 miles, and varies in breadth from 12 miles to 35. There is a smaller plain further down the river extending for about 80 miles from Barwai to the Harin Pal, south of Bágh, but it is comparatively ill-marked, the alluvial deposits are much less deep so far as is known, and no mammalian remains have been found in them. In the Tapti valley, there is a large plain in Khándesh, extending east and west for about 150 miles, and terminating to the eastward close to Burhánpúr. This plain lies chiefly to the north of the river, and is probably in places as much as 30 miles wide, but its limits have not been accurately determined. It appears to be connected by a narrow alluvial belt to the south-east with the plain of the Púrna,[1] a tributary of the Tapti, draining a great portion of Berar. The Púrna plain is at a higher level than Khándesh, and is about 100 miles long, and in places 40 miles broad, its eastern extremity being near Amráoti (Omrawattee), so that the whole length of the combined Tapti and Púrna plains is about 240 miles. The Tapti plain and both the Narbada plains are closed on the west by rocky and hilly country, through which the river has cut a channel with a rapid descent, and in the Narbada, as will be explained presently, it is ascertained that the upper alluvial basin extends to a considerable depth beneath the level of the river bed at the point of exit, so that the alluvial plain lies in a great rock basin.

In the valleys of the eastward-flowing rivers, such as the Godávari, Krishna and Káveri, there are no such broad and well-defined alluvial plains as in the drainage areas of the Tapti and Narbada. There are numerous extensive alluvial flats in many places, but they are far inferior in extent to the Narbada and Tapti plains, and they appear to be chiefly due to the river having worn a broad valley through soft, or easily disintegrated rocks. This is especially the case on the Godávari and its tributaries, the alluvial portions of the river valley being in the Gondwána series, or else in the Deccan traps, whilst the river traverses rocky gorges through the metamorphic rocks forming the various "barriers," at the places where the valley leaves the softer formations. On the Narbada and Tapti it is otherwise; the rocks underlying the alluvial areas, so far as they are known, are of the same kind as those cut through by the rivers at their exit from the plains. It is not improbable that the

[1] This is not quite certain, however, the ground not having been properly surveyed. There is a considerable amount of rock exposed in the rivers between the two plains, but the fall from one to the other cannot be much more than 100 feet to judge by the railway levels.

formation of these well-defined plains in the Narbada and Tapti valleys, and the absence of similar flats on the Godávari and Krishna, may be due to the rise of the Indian Peninsula in post-tertiary times having been, as already suggested, greater or more rapid to the westward than to the eastward.

Old alluvium of Narbada.—Partly in consequence of mammalian bones having been discovered in considerable quantities, and partly because the geology of the neighbouring country is of so much interest and variety as to have attracted the notice of many geologists, the alluvial deposits of the Narbada valley have received far more attention than similar formations on the banks of the other Indian rivers.[1] The great plain already mentioned as extending from Jabalpur to Harda is chiefly composed of a stiff, reddish, brownish or yellowish clay, with numerous bands of sand and gravel intercalated. Kankar abounds throughout the deposit, and pisolitic iron granules are of frequent occurrence in the argillaceous beds. Occasionally pebbles and sand are found cemented together by carbonate of lime so as to form a hard compact conglomerate. This rock is especially developed at the base of the alluvial deposits, and, not only in the Narbada, but in many other river valleys, it is often found forming a coating to the underlying rock. The clay is frequently quite devoid of stratification, but it appears never to attain any great thickness without sandy layers intervening. The river, in many places, cuts through the clays, sands and gravels to the underlying rock (usually belonging to the transition series), and the section of old alluvial deposits on the banks of the stream never greatly exceeds 100 feet in depth, this being about the usual difference in elevation between the bed of the Narbada and the general surface of the alluvial plain in the neighbourhood of the river. But in a boring which was made at Súkakheri, north of Mopáni and south of the Gádarwára station on the Great Indian Peninsula Railway, a depth of 491 feet was attained, without the base of the alluvial deposits being reached: another bore-hole was made through alluvial beds close to Gádarwára station to a depth of 251 feet. These bores were made for the purpose of ascertaining if the coal-bearing rocks of Mopáni extend to the northward; and the great depth of the alluvial deposits was quite unexpected. Throughout the thickness of nearly 500 feet, no change of importance was detected in the alluvial formations. By far the greater portion of the beds traversed consisted of clay with calcareous and ferruginous grains, sand and pebbles being found occasionally throughout. The bottom of the bore-hole was in lateritic gravel, and it is possible that rock was not far distant.

[1] For descriptions of the Narbada alluvial deposits, see Theobald, Mem. G. S. I., II, pp. 279-298. See also Mem. G. S. I., VI, pp. (227)-(232); Rec. G. S. I., VI, p. 49, VIII, p. 66.

The evidence thus obtained of the depth to which the alluvial deposits of the Narbada valley extend proves that they fill a rock basin, for the bed of the Narbada river, at the point where it leaves the alluvial plain near Hindia and commences to run through the rocky channel which extends to Barwai, is not more than 200 feet below the level of the surface at Gádarwára and Súkakheri, and the valley is surrounded by higher rocky ground in every other direction. A slight prolongation of the alluvial basin to the south-west in the direction of Harda, the prevalence of alluvium in parts of Nimar, and the circumstance that there is a great break by which the railway traverses the Sátpúra range, immediately east of Asirgarh, may indicate that the upper Narbada formerly joined the Tapti in Khándesh,[1] and that the lower valley of the former river as it now exists is due to changes of level in the later post-tertiary period.

The surface of the Narbada alluvium is undulating, and evidently denuded by the action of rain and streams. There is a slight slope of the surface to the westward throughout the plain; the elevation of the railway station at Harda, at the western extremity of the alluvial tract, being 947 feet above the sea, whilst Sohágpúr station is 1,103 feet, Narsingpúr 1,185, and Jabalpur, which, however, is on rock a little above the plain, 1,351. The fall of the surface in 200 miles is probably about 300 feet.

Palæontology.—Different views have been put forward as to the marine, lacustrine, or fluviatile origin of the Narbada alluvial deposits, but, before considering these, it will be well to give a list of the organic remains hitherto identified. They consist of bones and shells, and the following species have been determined[2] :—

VERTEBRATA.

MAMMALIA—
- Man (stone weapons).
- *Felis*, sp.
- *Ursus namadicus*, Pl. XX, fig. 6, molars.
- *Mus*, sp.
- *Elephas namadicus*, Pl. XX, fig. 5, molar, 8, skull.
- *E.* (*Stegodon*) *insignis*.
- *Rhinoceros namadicus*, Pl. XX, fig. 9, astragalus.
- *Equus namadicus*, Pl. XX, fig. 4, molars.
- *Hippopotamus* (*Hexaprotodon*) *namadicus*, Pl. XX, fig. 2, mandible.
- *H.* (*Tetraprotodon*) *palæindicus*, Pl. XX, fig. 7, molar.
- *Bos namadicus*, Pl. XX, fig. 3, frontlet.
- *B.* (*Bubalus*) *palæindicus*, Pl. XX, fig. 1, skull.
- *Cervus* (*Rucervus*) *namadicus*.

REPTILIA—
- *Emys* (*Pangshura*) *tectum*.
- *E.* (*Batagur*) conf. *dhongoka*.
- *Trionyx*, conf. *gangeticus*.
- *Crocodilus*, sp.

[1] The greatest elevation on the G. I. P. Railway, between the Narbada and Tapti valley, is 1,245 feet above the sea, or only 300 feet above Harda in the Narbada alluvial plain.

[2] Mem. G. S. I., II, pp. 284, 295 (these lists are not quite accurate); Rec. G. S. I., II, p. 36; VI, p. 54; IX, p. 88. The last is a list of the mammalia by Mr. Lydekker. See also Falconer, Pal. Mem., I, p. 21; II, p. 577, &c.

Note.—The species thus marked* are not determined with certainty, no specimens having been preserved in the Geological Museum.

MOLLUSCA.

GASTEROPODA—
Melania tuberculata.
Paludina bengalensis.
P. dissimilis.
* *Bythinia ceramecopoma.*
* *B. pulchella.*
Bulimus insularis.
* *Lymnea acuminata.*
Planorbis exustus.
* *P. compressus ?*

LAMELLIBRANCHIATA—
Unio corrugatus ? var.
U. indicus.
U. sp. near *U. shurtleffianus.*
U. marginalis.
Corbicula, sp., near *C. striatella.*

The only trace of man hitherto found in these deposits consists of a chipped stone scraper or hatchet[1] (Pl. XXI, fig. 1), discovered by Mr. Hacket *in situ* near the village of Bhutra, 8 miles north of Gádarwára. The material is Vindhyan quartzite, and the form similar to that of some of the implements found in the lateritic deposits of Southern India, and in the post-pliocene formations of Europe.

The mammalian forms related to existing Indian species are *Elephas namadicus*, allied to the existing Indian elephant, *Bos palæindicus*, very close to the living Indian wild buffalo, and *Cervus namadicus*, a near relation to the Bárasingha (*Cervus duvaucelii*). On the other hand, *Elephas insignis* and *Hippopotamus namadicus* belong to extinct sub-genera, the first being common to the pliocene Siwalik rocks, and the latter replaced by a nearly allied species. *Hippopotamus palæindicus* and *Bos namadicus* are not nearly allied to any Indian living species; the first belongs to a genus now only found in Africa, whilst the second, although having some characters in common with the living wild cattle of India *Bos* (*Bibos*) *gaurus*, differs from the latter in many important particulars, and appears to be quite as closely connected with true taurine oxen belonging to the type of *Bos taurus*. *Bos namadicus*, indeed, cannot be classed in the sub-division *Bibos*. The relations of the remaining mammals are less distinctly made out, the specimens on which the species are founded being for the most part fragmentary.

The only reptile clearly identified is *Emys tectum*, which is considered identical with a living Indian form. It is very singular that only fragmentary remains of crocodiles occur, for they abound in the Siwalik rocks, and a species is common in the Narbada at the present day. The mollusca appear to be the same as species now living in the area, and all the commonest forms now known to occur in the river valley are represented,[2] except some minute species of land shells.

[1] Rec. G. S. I., VI, p. 49; two figures of the implement are given.

[2] The only exception of any importance is *Melania spinulosa*, but that is not by any means so generally distributed a form as *M. tuberculata*. The absence in the Narbada deposits of *Melania variabilis* and *M. spinulosa*, the latter of which is included in Mr. Theobald's lists of living Narbada species, Mem. G. S. I., II, p. 287, was noticed by Dr. Falconer, Q. J. G. S., 1865, p. 382, but it is extremely doubtful whether *M. variabilis* does exist in the Narbada valley or its neighbourhood. The occurrence of *M. lyrata*, included in Mr. Theobald's list, l. c., is also very doubtful.

Their absence is not surprising, because land shells, for the most part, float when washed away, and are left on the surface, where they decompose instead of being preserved in alluvial deposits.[1]

Fluviatile origin of Narbada alluvium.—The examination of the molluscan remains in the Narbada clays and gravels completely disproves the idea of a marine origin, but it has been considered by some observers that the deposits are lacustrine.[2] This view was principally based upon the uniform appearance of the clay and the absence of stratification. But this very uniformity and want of stratification are common characters of undoubted river deposits, and may be observed on the banks of most large streams, whilst the frequent deposition of pebble beds throughout the clays could not have taken place in the waters of a large lake. The bones, too, are isolated and broken, sometimes being even rolled, whereas, if deposited in a lake, different bones would in all probability be found together, because away from the margin there could be no current in the lake of sufficient force to transport bones divested of flesh, and any mammalian remains deposited in the bottom of the lake must be derived from floating carcases or portions of carcases. Moreover, the *Chelonia* and fresh-water mollusca are all forms which inhabit either rivers or shallow marshes in river valleys, and it is improbable, if so great a change took place in the area, as would be involved in the replacement of immense lakes, or chains of lakes, by a river valley, that a greater difference would not be produced between the tortoises and fresh-water shells formerly inhabiting the waters and those still living. On the other hand, the fact, that the alluvial formation occupies a rock basin, shews that if the deposits were produced by a river, a considerable upheaval of land must have taken place to the westward. The river Narbada, moreover, is now no longer a depositing stream within the alluvial basin; on the contrary, it has cut its way through a considerable thickness of clays, and it must therefore have a greater fall than formerly. This, of course, may be due to the rocky edge of the basin having been cut through by the river, and by the channel of exit being consequently at a lower level.

Tapti and Purna alluvial plains.—The alluvial plains of the Tapti valley require but brief notice.[3] In their principal characters they resemble the Narbada plain, but the depth of the deposits is unknown, no deep borings having been made. As in the Narbada valley, the river now runs at a considerable depth below the alluvial plain,

[1] See Mem. G. S. I., VI, p. (231).

[2] Mem. G. S. I., II, p. 283.

[3] For a few additional details see Mem. G. S. I., VI, pp. (276), (286); and Wynne, Rec. G. S. I., II, p. 1.

and is evidently cutting its channel deeper, and not depositing at present. The whole basin is composed of the Deccan trap, and the Tapti cuts its way out to the westward through the same formation. No remains of mammalia have hitherto been detected in the alluvium, but they will probably be found if sought after; the few mollusca found, as in the Narbada plain, belong to recent fresh-water species inhabiting rivers.

The difference in elevation between the Tapti and Púrna plains is not accurately known, nor are the levels of different parts of the plains well determined, the only data available being those furnished by the railway. The height above the sea at Bhosawal, just south of the alluvial flat, near the eastern extremity of Khándesh, is 677 feet. This cannot be much above the flood-level of the Tapti river, for the rail-level at the bridge over the Tapti, only about 6 miles distant, is 685 feet. At Malkapur, close to the western extremity of the Púrna alluvial plain, the level is 816 feet, at Akola 917, at Murtazapur 986, and at Badnera, south of Amráoti, 1,093. The last locality, however, is some miles distant from the south-eastern edge of the alluvium, and none of the railway stations are out in the alluvial plain as in the Narbada valley.

The only peculiarity of the Púrna alluvial deposits which deserves notice is the occurrence of salt in some of the beds at a little depth below the surface. Throughout an area more than 30 miles in length, extending from the neighbourhood of Dhyanda, north of Akola, to within a few miles of Amráoti, wells for the purpose of obtaining brine are sunk in several places on both sides of the Púrna river. The deepest wells are about 120 feet deep; they traverse clay, sand and gravel, and finally, it is said, a band of gravelly clay, from which brine is obtained. No fossils are found in the clay and sand dug from the wells. The occurrence of salt in the alluvial deposits of India is not uncommon, and it is impossible to say, without further evidence, whether it indicates the presence of marine beds. The absence of marine fossils in all known cases is opposed to any such conclusion, but still it is not impossible that the land may have been 1,000 feet lower than it now is in late tertiary, or early post-tertiary, times, and this difference in elevation would depress the Púrna alluvial area beneath the sea-level.

Older alluvial deposits of Godavari.—It has already been mentioned that the alluvial deposits of the Godávari do not occur in distinct basins like those of the Narbada and Tapti, but the river in general has but a slight fall, and forms a broad alluvial plain where it traverses softer beds, whilst it cuts a steeper slope through harder rocks.

There is an exception to the latter rule in the gorge above Rájámahendri. Extensive alluvial areas occur along the upper part of the Godávari in the Bombay Presidency and the adjoining portion of the Nizam's dominions, and similar tracts are found on the Pen Ganga (Pyne or Pem Ganga), Wardha, and Wain Ganga, tributaries of the Godávari, in Berar, Nágpúr, and Chánda.

The composition of these deposits differs in no important particular from that of the Narbada and Tapti alluvium. The gravels are chiefly composed of rolled agates and fragments of basalt derived from the Deccan traps, which are the prevailing rocks in the upper part of the valley. The greater portion of the alluvium in all cases consists of brown clay with kankar. In the Wardha valley beneath the clays and calcareous conglomerates some fine sandy silt, light brown or grey in colour, occurs west of Chánda, and contains salt, with a considerable proportion of sulphate of magnesia[1] (Epsom salts).

Bones of mammalia have been found—sometimes, it is said, in large numbers—in the Godávari valley, but very few appear to have been preserved, and the only species identified is *Elephas namadicus*.[2] Bones of *Bos* and other animals occur, and it appears probable that the fauna is similar to that of the Narbada valley. From the gravels near Múngi and Paitan (Pytun) on the road from Ahmednagar to Jálna, Mr. Wynne obtained an agate flake[3] (Pl. XXI, fig. 2), apparently of human manufacture, thus affording a second instance of traces of man occurring in the post-tertiary river gravels of the Peninsula.

The most important localities at which bones have been observed are the neighbourhood of Múngi and Paitan already mentioned, and one or more places on the Pen Ganga or its tributaries in the neighbourhood of Hingoli.[4] At one spot near Hingoli bones are said to have been found in immense quantities, but unfortunately they were not preserved.

Krishna Valley.—The valley of the Krishna, in many respects, resembles that of the Godávari; there are similar plains of alluvial clay with beds of sand, gravel and calcareous conglomerate, but none of these plains appears to be of great extent. Beds of gravel at a height of 60 to 80 feet above the present course of the river and its tributaries have been observed in many places.[5]

[1] Rec. G. S. I., IV, p. 80; Mem. G. S. I., XIII, p. 92.

[2] Falconer, Q. J. G. S., 1865, p. 381; Mem. G. S. I., VI, p. (232).

[3] For a description by Dr. T. Oldham and figures, see Rec. G. S. I., I, p. 65.

[4] Captain O. W. Gray, Mad. Jour. Lit. Sci., VII, p. 477 (1838): Carter on the authority of Dr. Bradley, J. B. Br. R. A. S., V, p. 304: Newbold, J. R. A. S., VIII, p. 246. See also Mem. G. S. I., VI, p. (232).

[5] Newbold, J. R. A. S., VIII, p. 247: Foote, M. G. S. I., XII, p. 237, &c.

The only important mammalian remains[1] hitherto found in the alluvial deposits of the Krishna and its tributaries, consist of portions of the cranium and mandible of a *Rhinoceros*, and some bovine teeth and jaws, found on the Ghatprabha near the town of Gokák. The bovine remains have not been determined; the *Rhinoceros* has been described under the name of *R. deccanensis* by its discoverer, Mr. Foote.[2] The species differs widely from all living forms, and does not appear to be very nearly connected with any known fossil Indian species. Some fresh-water shells, of living species, were found with the bones.

It was probably from some part of the upper drainage area of the Krishna, also, that Colonel Sykes obtained the teeth of a trilophodont *Mastodon*, described by Falconer[3] under the name of *M. pandionis*, Lartet.

Large numbers of chipped quartzite implements of human manufacture, and belonging to the same type as that discovered in the Narbada alluvium, have been found in various gravels in the Southern Máhratta country on the Malprabha and other affluents of the Krishna.[4] The relations between the ossiferous gravels and those containing the implements are, however, somewhat obscure.

Nothing of importance is known concerning the older alluvial deposits of the remaining rivers in the Indian Peninsula.

It is in the Máhánadi, Krishna, and Pennár valleys that the principal diamond gravels are found, frequently at heights considerably above the present stream level.[5] The pebbles in the gravels are composed of various kinds of metamorphic and transition rocks.

[1] Mem. G. S. I., XII, p. 232.
[2] Pal. Ind., Ser. X, 1.
[3] Pal. Mem., 1. 124.
[4] Foote, Mem. G. S. I., XII, p. 241.
[5] Newbold, Jour. Roy. As. Soc., VII, p. 226.

CHAPTER XVII.

PENINSULAR AREA.

POST-TERTIARY AND RECENT—(*continued.*)

Indo-Gangetic alluvium: area and elevation — Origin of the Gangetic plain: no evidence of marine conditions in Upper India — Sub-recent marine conditions in the Indus area — Character of Indo-Gangetic alluvium — Calcutta borehole — Umballa borehole — Fossils in Indo-Gangetic alluvium — General surface features of the Indo-Gangetic plain — Bhábar, Terai, Bhángar, and Khádar — Bhúr land — The Brahmaputra valley in Assam — The delta of the Ganges and Brahmaputra — Mr. Fergusson's theories — The Madapúr jungle — The plains of Upper Bengal and the North-West Provinces — Kalar or Reh — Salt wells — The Punjab — Ancient changes in the course of the Punjab rivers — The lost river of the Indian desert — The Lower Indus valley and delta — The Ran of Cutch.

Indo-Gangetic alluvium: area and elevation.—The immense alluvial plain of the Ganges, Indus, and Brahmaputra rivers and their tributaries, the richest and most populous portion of India, covers an area of about 300,000 square miles, and forms approximately one-fourth of the whole surface of British India exclusive of Burma. The greater part of the provinces known as Assam, Bengal (including Behár), the North-West Provinces, Oudh, the Punjab and Sind, are included in the great plain, which, varying in width from 90 to nearly 300 miles, entirely separates the geological region of Peninsular India from the Himalayas to the north, the Sulemán and Khirthar ranges to the west, and the hill regions of Assam, Tipperah, and Chittagong to the eastward. Owing to the varying extent to which the surface is raised on the margins of the area by the detritus brought by rivers from the hills, and the gradation between the finer deposits of the plain and the coarser gravels forming a detrital slope at the base of the Himalayas, it is difficult to estimate exactly the greatest height of the plain above the sea; the highest level recorded by the Great Trigonometrical Survey between the Ganges and Indus, on the road from Sahåranpur to Ludhiana, is 924 feet,[1] and

[1] The following elevations of localities in the Indo-Gangetic plain will afford some idea of the general height of the surface above the sea. The figures, except in the case of Rájmahál, are taken from the maps and published sections of the Great Trigonometrical

this may be fairly taken as the summit level at the lowest part of the watershed between the Indus and the Ganges. There is no ridge of high ground between the Ganges and Indus drainage, and a very trifling change in the surface might at any time turn the affluents of one river into the other. It is reasonable to infer that such changes have taken place in past times, and that the occurrence of closely allied species of *Platanista* (a fresh-water dolphin peculiar to the Indus, Ganges, and Brahmaputra) in the two rivers, and of many other animals common to both streams, may thus be explained.[1]

Survey, with a few additions kindly furnished by the Surveyor General, Colonel Walker. At all the localities quoted, the height is the approximate level of the plain:

1. Brahmaputra Valley.

Sadiya	440	Sibsagar	319	Gauhati	163
Dibrugarh	348	Buramuk near Tezpur	256	Goalpara	150

2. Ganges Valley.

Burdwan	102	Allahabad	319	Delhi	715
Rájmahál	68	Cawnpore	417	Meerut	739
Benares	258	Agra	553	Sahárunpur	907

3. Indus Valley.

Umballa	901	Dera Ismail Khan	595	Shikarpur	198
Ludhiana	806	Mooltan	407	Sehwan	110
Ferozepoor	615	Baháwalpur	375	Kotri	66
Lahore	708	Kashmor	246		

[1] The occurrence of allied forms of porpoise or dolphin in the Ganges and Indus, and the circumstance that the peculiar genus living in these rivers is unknown elsewhere (the cetacean inhabiting the Irawadi being of a very different generic type), have attracted the attention of naturalists already. The ova and young of fish are not difficult of transport, and a very trifling accident might place a pool of water, to which the fish of one river have gained access, in communication with the other stream; crocodiles and river tortoises can live for a long time out of water, and have considerable powers of migration on land; but dolphins are confined to the rivers, and could neither live in a shallow pool, nor traverse dry land; the existence, therefore, of closely allied species, doubtless derived from a common ancestor, in two distinct rivers, is a very striking fact. Mr. Murray (Geographical Distribution of Mammals, p. 213) has proposed an ingenious hypothesis to account for the phenomenon. He considers that the plain of Upper India was once an arm of the sea; that it was cut off by the rise of the coast in Sind and Cutch, and gradually converted into a brackish, and then a fresh-water lake, discharging itself by the Ganges; that meantime the marine dolphins inhabiting the sea had gradually become adapted to the changed conditions, and had in fact become *Platanistæ*. He then supposes that the Ganges was cut off from the lake, which overflowed again, and this time into the Arabian sea, the dolphins of the Ganges and Indus being specialised during the change. It would be unnecessary to refer to this hypothesis, which of course is little more than a suggestion, but for the large amount of support the idea has received from naturalists. It is of course foreign to the purpose of the present work to discuss the genesis of *Platanista*, but, as will be shewn, the geological phenomena of the Indo-Gangetic plain do not bear out Mr. Murray's hypothesis, which, however, it should be stated, was never proposed as a geological theory, but merely as illustrative of the possible mode of origin of allied species.

No evidence of marine conditions in Upper India.—A common idea amongst both geologists and naturalists is, that the great Indian plain was an arm of the sea in late geological times.[1] It is possible that this may have been the case, but there is absolutely no evidence whatever in favour of such a view, and some facts are opposed to it. On the southern flank of the Himalayas, no marine formations have been discovered of later date than eocene, and even eocene marine beds are unknown, except in one place east of the Ganges, between the spot where the Jumna leaves the Himalayas, and the Gáro hills, or throughout 13 degrees of longitude; whilst the later tertiary formations, belonging to the Siwalik series, contain fresh-water *Reptilia* and *Mollusca*, and not a single marine shell has been found in them. In Sind, marine beds of miocene date are found, and it is possible that strata of the same age may extend to the Punjab, but in the Salt Range the fresh-water Siwaliks rest upon the nummulitic limestone. It is true that it is impossible to tell what beds may be concealed beneath the Indo-Gangetic alluvium, and marine strata may exist to an enormous extent without appearing at the surface; it is also unquestionable that the amount of information hitherto derived from borings is very small indeed, but so far as that information extends, and so far as the lower strata of the alluvial plain have been exposed in the beds of rivers, not a single occurrence of a marine shell has ever been observed, nor is there such a change in the deposits as would render it probable that the underlying strata are marine. As will be shewn presently, the lowest deposits known in the plain itself are of post-tertiary age, and they are certainly fresh-water, whilst the tertiary deposits are chiefly known to occur on the northern margin of the plain. The older pliocene deposits of Perim Island in the Gulf of Cambay lie, however, to the south of the alluvial area, and five species of mammals found in them, *viz.*, *Mastodon latidens*, *M. perimensis*, *M. sivalensis*, *Acerotherium perimense*, and probably *Sus hysudricus*, are also met with in the Siwaliks at the base of the Himalayas, so that there was probably land communication between the two areas. The only evidence known in favour of marine conditions having prevailed during the deposition of any portion of the Gangetic alluvium is the occurrence of brine springs at considerable depths in a few localities. These springs, however, are not numerous, and, without additional evidence, it is impos-

[1] Hooker's Himalayan Journals, I, p. 378: Theobald, Rec. G. S. I., III, p. 19. Mr. Theobald's main argument, derived from the clay at Patharghatta, has been shewn by a re-examination of the locality to be untenable, the deposit in question being merely a surface wash, containing fragments of bricks amongst other things; see Ball, Mem. G. S. I., XIII, p. (224). Dr. Falconer, Pal. Mem., I, p. 29, considered that the Indo-Gangetic area was formerly an arm of the sea, but that it had been converted into land before the Siwalik epoch.

sible to look upon them as proofs of marine deposits. At the same time, it is by no means impossible that the sea occupied portions of Sind and Bengal long after the plain of Upper India was dry land. With reference to Bengal, there is very little evidence. Mr. Fergusson, in a masterly essay on recent changes in the delta of the Ganges,[1] has brought forward a quantity of historical data tending to shew that the whole Ganges valley 5,000 years ago was probably not habitable, and that the extension of human settlements to the eastward from the Punjab has been gradual. This, however, may all be conceded, with the reservation that additional evidence as to the previous want of population is desirable; the Ganges valley 5,000 years ago, like that of the Brahmaputra valley at the present day, may have been so swampy as to be ill-suited for cultivation, and yet there is no reason for supposing that the area had recently been covered by the sea, for the state of the surface may have been due to an amount of depression sufficient to render the area marshy, but not enough to cause it to be overflowed by the ocean. That depression has taken place in the delta, is shewn by the records of the Fort William borehole, to be described presently. The only known marine beds[2] in the neighbourhood of the Ganges delta, those at the foot of the Gáro hills, are apparently of tertiary age, and probably pliocene.

Sub-recent marine conditions in the Indus area.—In the Indus valley some proof has lately been obtained, shewing that the sea may have occupied part of the area in post-tertiary times.[3] East of the alluvial plain of the Indus near Umarkot (Omerkote) is a tract of blown sand, the depressions in which are filled by salt lakes. These lakes are supplied by water trickling through the soil from large marshes and pools supplied by the flood waters of the rivers, and it is evident that

[1] Q. J. G. S., 1863, p. 321. There is one ethnological fact which Mr. Fergusson has not noticed. He considers that Lower Bengal was not habitable 1,000 years ago. Now the population of Bengal, as any one who has seen much of Indian races will probably admit, is shewn by colour, physique, and habits of life to contain a large proportion of the non-Aryan races; the people of Upper India, on the other hand, having a much larger Aryan element. But if the non-Aryan race did not inhabit the country before the advent of the Mahomedans, how comes it that this race is now a preponderating constituent of the population? The mixed race may have migrated into the country, but it is at least as probable that the non-Aryan tribes were indigenous, and that the present Bengali race is due to an admixture of Aryan blood. The point is, whether Mr. Fergusson has not overlooked the fact that the Aryan immigrants are certainly not the oldest inhabitants of India, and whether, as no history of the indigenous races exists, he may not have taken the south-eastern migration of the more civilised population amongst uncivilised tribes for the original peopling of the Gangetic plain.

[2] Colebrooke, Geol. Trans., Ser. 2, Vol. I, p. 135.

[3] J. A. S. B., 1876, XLV, Pt. 2, p. 93; Rec. G. S. I., X, pp. 10, 21.

the depressions amongst the sand-hills are at a lower level than the alluvial plain, and that the salt is derived from the soil beneath the sand. To the southward is a great flat salt tract known as the Ran of Cutch, marshy in parts, dry in others, throughout the greater part of the year, but covered by water when the level of the sea is raised by the south-west monsoon blowing into the Gulf of Cutch and the old mouth of the Indus, and all water which runs off the land is thus ponded back. The Lúni river, which flows into the Ran, is, except after rain, extremely salt, and salt is largely manufactured from the salt earth at Pánchbhadra, close to the Lúni, more than 100 miles from the edge of the Ran, and nearly 300 from the sea. Both the present condition of the Ran and tradition point to the area having been covered by the sea in recent times, and having been filled up by deposits from the streams running into it; and the occurrence in some of the salt lakes near Umarkot, 150 miles from the sea, of an estuarine mollusk *Potamides* (*Pirenella*) *layardi*, common in the salt lagoons and back-waters of the Indian coast, seems to indicate that these lakes were formerly in communication with the sea. The enormous quantity of blown sand, also, which covers the Indian desert, can only be satisfactorily explained by supposing that it was derived from a former coast line north of the Ran and east of the Indus valley.[1]

It appears probable that in post-tertiary times an arm of the sea extended up the Indus valley at least as far as the salt lakes now exist, or to the neighbourhood of Rohri, and probably farther, and also up the Lúni valley to the neighbourhood of Jodhpur; the Ran of Cutch being of course an inland sea.[2] The country to the westward has been raised by the deposits of the Indus, and the salt lakes have been isolated by ridges of blown sand.

It is true that along the western margin of the Indus alluvium later tertiary rocks (Manchhar) are found containing remains of mammalia, and precisely resembling the Siwalik formation, and as there is nevertheless a probability that the lower Indus valley was an arm of the sea in post-tertiary times, it may fairly be argued that the existence of the Sub-Himalayan Siwaliks is no proof that the Ganges valley was not an inland sea at the same epoch. But in the Indus region the representatives of the Siwaliks pass downwards into miocene marine beds; in lower

[1] A description of this area will be found at the end of the present chapter, and the Indian desert is described in the chapter following.

[2] Some additional evidence in favour of this view will be mentioned in the next chapter in connexion with the distribution of blown sand in the desert between Sind and Rajpútána.

Sind the Manchhar formation itself becomes interstratified with bands containing marine shells, and not very far to the westward, on the Baluchistan coast, there is a very thick marine pliocene formation, so that there is evidence in abundance of the sea having occupied portions of the area in later tertiary times, whilst there is no proof of any such marine conditions in the Ganges plain.

Character of Indo-Gangetic alluvium.—The various deposits of the Indo-Gangetic plain[1] may be roughly classed under two sub-divisions, older and newer; the former consisting of beds which are, where exposed, undergoing denudation; whilst the latter form the newer accumulations, the flood and delta deposits now in process of formation. It is difficult, if not impossible, to draw any distinct line of separation between these two sub-divisions, unless, as but rarely occurs, they contain fossils characteristic of their age, but, generally speaking, all the higher ground is composed of older deposits, whilst the newer alluvium is chiefly confined to the neighbourhood of the river channels, except in the delta of the Ganges and in the Brahmaputra plain. Still there are large parts, both of the Indus and Ganges plains, which are flooded every season, and on these areas newer deposits are formed by the flood waters. Moreover, as the rivers constantly change their courses, they often sweep away deposits only a few years, or even a few months old.

The prevailing formation throughout the Indo-Gangetic alluvial area is some form of clay, more or less sandy. The older deposits generally contain kankar; the newer deposits do not as a rule, but there are numerous exceptions in both cases. In the Indus valley the alluvial deposits are much more sandy than in the Ganges valley, and the surface of the ground is paler in colour, except where marshy conditions prevail. The deposits of the Brahmaputra valley in Assam are also sandy. In both these valleys nearly the whole area is occupied by the newer alluvial deposits, whilst the greater portion of the Ganges plain, except towards the delta, is composed of an older alluvial formation.

The older alluvium is usually composed of massive clay beds of a rather pale, reddish-brown colour, very often yellowish when recently exposed to the air, with more or less kankar disseminated throughout. In places, and especially in Bengal and Behár, pisolitic concretions of hydrated iron peroxide, from the size of a mustard seed to that of a pea,

[1] The authorities for the following account are manuscript reports by Mr. Theobald on parts of the alluvial area in Bengal, Behár, and the North-Western Provinces, some extracts from which were published, Rec. G. S. I., III, p. 17; sketch of the Geology of the North-Western Provinces, Rec. G. S. I, VI, p. 9, and various papers to which reference is made in notes.

are disseminated through the clay; occasionally these nodules attain larger dimensions, some being found near Dinájpur (Dinagepore) of the size of pigeons' eggs. In places the kankar forms compact beds of earthy limestone. Sand, gravels, and conglomerates occur, but are, as a rule, subordinate, except on the edges of the valley, the quantity of sand in the clay decreasing gradually as the distance from the hills increases. Pebbles are scarce at a greater distance than from 20 to 30 miles from the hills bordering the plain. Beds of sandstone, sufficiently compact for building, have occasionally been found, but they are of rare occurrence. On the whole, there is no great difference between the alluvial formations of the Indo-Gangetic plain and those of the Narbada and Tapti, except that the latter are rather darker in colour, and perhaps less sandy.

The newer alluvial deposits consist of coarse gravels near the hills, and especially at the base of the Himalayas, sandy clay and sand along the course of the rivers, and fine silt consolidating into clay in the delta and in the flatter parts of the river plain. In the Ganges delta, beds of impure peat commonly occur. Fresh-water shells are of more frequent occurrence in the newer forms of alluvium than in the older, the species being of course those now living in the rivers and marshes of the country.

The denudation of rivers has in some parts of the North-West Provinces cut through the older alluvial clays to a depth occasionally, as on the Chambal river, amounting to nearly 200 feet. Of the whole thickness attained by the alluvial deposits of the great Indian rivers, not the faintest idea can be formed. It must be very great, or rock would be exposed within the alluvial area to a greater extent than it is. The only information of importance hitherto procured as to the nature and depth of the alluvial deposits beneath the surface is derived from three borings: one, 481 feet deep, at Fort William, Calcutta, within the delta and close to a tidal river; the second at Umballa, 701 feet deep, at nearly the highest level of the plain away from the slope of detritus along the margin; the third, carried to a depth of 464 feet, at Sabsal-ka-kot on the right (west) bank of the Indus, about 21 miles east by north of Rajánpur and about 400 feet above sea-level. All these boreholes were made for the purpose of obtaining water.

Calcutta borehole.—The Calcutta borehole is on the whole the most important, because it was carried down to a depth of about 460 feet below the mean sea-level. The following account of the deposits passed through in the borehole is taken from the "Abstract report of the Proceedings of the Committee appointed to superintend the bore

operations in Fort William from their commencement, December 1835, to their close in April 1840[1]:—

"After penetrating through the surface soil to a depth of about 10 feet, a stratum of stiff blue clay, fifteen feet in thickness, was met with. Underlying this was a light-coloured sandy clay, which became gradually darker in colour from the admixture of vegetable matter, till it passed into a bed of peat, at a distance of about 30[2] feet from the surface. Beds of clay and variegated sand intermixed with kankar, mica, and small pebbles, alternated to a depth of 120 feet, when the sand became loose and almost semi-fluid in its texture. At 152 feet the quicksand became darker in colour and coarser in grain, intermixed with red water-worn nodules of hydrated oxide of iron, resembling to a certain extent the laterite of South India. At 159 feet a stiff clay with yellow veins occurred, altering at 163 feet remarkably in colour and substance, and becoming dark, friable, and apparently containing much vegetable and ferruginous matter. A fine sand succeeded at 170 feet, and this gradually became coarser and mixed with fragments of quartz and felspar to a depth of 180 feet. At 196 feet clay impregnated with iron was passed through, and at 221 feet sand recurred, containing fragments of limestone with nodules of kankar and pieces of quartz and felspar; the same stratum continued to 340 feet, and at 350 feet a fossil bone, conjectured to be the humerus of a dog, was extracted.[3] At 360 feet a piece of supposed tortoise shell[4] was found, and subsequently several pieces of the same substance were obtained. At 372 feet another fossil bone was discovered, but it could not be identified, from its being torn and broken by the borer. At 392 feet a few pieces of fine coal, such as are found in the beds of mountain streams, with some fragments of decayed wood, were picked out of the sand, and at 400 feet a piece of limestone was brought up. From 400 to 481 feet fine sand, like that of

[1] J. A. S. B., 1840, IX, p. 686. See also an excellent account by Lieutenant (afterwards Colonel) R. Baird Smith, Calcutta Jour. Nat. Hist., I, p. 324, pl. ix, and Proc. Geol. Soc., IV, p. 4. From the latter the account in Lyell's Principles of Geology appears to be chiefly taken. Some additional details will be found in the Jour. As. Soc. Bengal, II, pp. 369, 649; IV, p. 235; V, p. 374; VI, pp. 234, 321, 498, 897; VII, pp. 168, 466.

[2] Eighty feet in the original, but this is almost certainly a misprint;—first, because Lieutenant Baird Smith mentions in his description the occurrence of peat between 30 and 50 feet from the surface, whereas from 75 to 120 feet sandy clay is said to occur, and this agrees with his descriptive catalogue of the specimens extracted from the borehole, and with his figured section;—secondly, because, as will be shewn hereafter, a bed of peat is found everywhere around Calcutta at a depth of 20 to 30 feet.

[3] A ruminant bone according to Dr. Falconer; Lyell's Principles, ed. 1867, I, p. 479. The specimen cannot now be found. Figures of this bone are given, J. A. S. B., VI, p. 234, pl. xviii; and Calc. Jour. Nat. Hist., I, pl, ix.

[4] Figured J. A. S. B., VI, p. 321, pl. xxi; and Calc. Jour. Nat. Hist., I, pl. ix.

the sea-shore, intermixed largely with shingle composed of fragments of primary rocks, quartz, felspar, mica, slate, and limestone, prevailed, and in this stratum the bore has been terminated."[1]

The first and most important observation to be made on the foregoing facts is that not race of marine deposits was detected, but on the contrary there appears every reason for believing that the beds traversed, from top to bottom of the borehole, had been deposited either by fresh water, or in the neighbourhood of an estuary. At a depth of 30 feet below the surface, or about 10 feet below mean tide-level, and again at 382 feet, beds of peat with wood were found, and in both cases there can be but little doubt that the deposits proved the existence of ancient land surfaces. The wood in the upper peat beds was examined by Dr. Wallich and found to be of two kinds, one of which was recognised as belonging to the Súndri tree (*Heritiera littoralis*), which grows in abundance on the muddy flats of the Ganges delta, the other probably as the root of a climbing plant resembling *Briedelia*. Moreover, at considerable depths, bones of terrestrial mammals and fluviatile reptiles were found, but the

[1] The following details are taken from the figured section by Lieutenant Baird Smith, l. c. :—

	Thickness in feet.	Depth in feet.
Surface soil, loose sand, and clay	10	...
Adhesive blue clay	15	25
Ditto with peat	10	35
Adhesive clay	5	40
Dark clay with decayed wood intermixed	10	50
Calcareous clay with kankar	10	60
Green silicious clay; Silicious clay with kankar; Variegated arenaceous clay — Details of thickness not given, the lower portion represented as much thicker than the others.	60	120
Argillaceous marl	5	125
Loose sandstone	5	130
Argillaceous marl	20	150
Arenaceous clay with weathered mica slate and nodules of hydrated oxide of iron	20	170
Calcareous clay	5	175
Coarse friable quartzose conglomerate	10	185
Micaceous clay	20	205
Soft sandstone	5	210
Ferruginous sand intermixed with clay	90	300
Fine loose sand with minute fragments of felspar and granite	25	325
Sandstone slightly aggregated (first fossiliferous stratum 350 feet)	55	380
Shelly calcareous clay	5	385
Carbonaceous bed	10	395
Coarse conglomerate third fossiliferous stratum 430 feet)	86	481

only, fragments of shells noticed, at 380 feet, are said to have been of fresh-water species.

The next noteworthy circumstance is the occurrence at a depth of 175 to 185 feet, again at 300 to 325, and again throughout the lower 85 feet of the borehole, of pebbles in considerable quantities. The pebbles in the lower portion are especially mentioned as large, and their size is shewn by the circumstance that they impeded the progress of the bore, and that it was necessary in several cases to break them up before they could be extracted, so that it may be fairly inferred that they were at least two to three inches across (the borehole was six inches in diameter). The greater part of the pebbles were clearly derived from gneissic rocks, but some fragments of coal and lignite which were obtained were perhaps from the Damuda series.

The peat bed, it may here be mentioned, is found in all excavations around Calcutta, at a depth varying from about 20 to about 30 feet, and the same stratum appears to extend over a large area in the neighbouring country.[1] A peaty layer has been noticed at Canningtown on the Mutlah, 35 miles to the south-east, and at Khulna, in Jessore, 80 miles east by north, always at such a depth below the present surface, as to be some feet beneath the present mean tide-level. In many of the cases noticed, roots of the *sundri* tree were found in the peaty stratum. This tree grows a little above ordinary high-water mark in ground liable to flooding; so that in every instance of the roots occurring below the mean tide-level, there is conclusive evidence of depression. This evidence is confirmed by the occurrence of pebbles; for it is extremely improbable that coarse gravel should have been deposited in water 80 fathoms deep, and large fragments could not have been brought to their present position, unless the streams, which now traverse the country, had a greater fall formerly, or unless, which is perhaps more probable, rocky hills existed, which have now been partly removed by denudation and covered up by alluvial deposits. The coarse gravels and sands which form so considerable a proportion of the beds traversed can scarcely be deltaic accumulations, and it is therefore probable that when they were formed, the present site of Calcutta was near the margin of the alluvial plain, and it is quite possible that a portion of the Bay of Bengal was dry land.[2]

[1] Baird Smith, l. c.; H. F. Blanford, J. A. S. B., 1864, XXXIII, p. 154. See also notices of earlier borings, &c., J. A. S. B., II, pp. 369, 649.

[2] But whilst the evidence of depression to a depth of nearly 500 feet, probably since tertiary times, in the neighbourhood of Calcutta, is unmistakable, the signs already mentioned of elevation within the same epoch in Orissa, only 100 to 200 miles distant to the south-west, are equally distinct, and this proof of unequal movement suffices to shew the hazard of supposing that the general form and direction of the river valleys in the neighbourhood have remained unchanged since the lowest mesozoic, or even the upper palæozoic period; see *ante*, p. 105.

Umballa borehole.—The following is an abstract of the beds traversed in the Umballa borehole.[1] Umballa, it may be mentioned, is on the watershed of the Indo-Gangetic plain, between the Jumna, which flows into the Ganges, and the Sutlej, a tributary of the Indus. The locality is about 905 feet above the sea, and 20 miles from the base of the Himalayas.

	Thickness in feet.	Depth in feet.
Surface soil	4	4
Sand, more or less argillaceous, and clay	22·5	26½
Brown clay and kankar	·5	27
Sand	14	41
Clay, blue and brown	81	122
Sand and clay with kankar	32	154
Dark red clay	12	166
Sand and clay, with bands of kankar	84	250
Stiff red clay and pebbles	14	264
Sand and clay, with kankar occasionally	22	286
Coarse sand, with clay boulders and small stones	10	296
Very stiff clay, with pebbles and boulders	1·5	297½
Clay, with kankar and some sand	12·5	310
Sandy clay, with mica	8	318
Alterations of sand and clay, with kankar occasionally	78	396
Sand and gravel, with large stones	28	424
Clay, with thin bands of fine sand or silt	27	451
Dark sand, with clay boulders and kankar	5	456
Sand and clay	44	500
Clay, with stones	2	502
Sand and clay, with kankar	32	534
Clay boulders, kankar and sand	12	546
Clay, some kankar in the upper portion	39	585
Blue sand, with boulders in the lower portion	16	601
Clay	14	615
Clay, with kankar and pebbles	2·5	617½
Clay, with some kankar	23·5	641
Black clay	3	644
Clay, with kankar in uppermost part	34	678
Sand, which hardens when exposed to air	5	683
Clay, with kankar	18	701

It is not quite clear what is meant by "clay boulders"; they are probably rolled fragments of the clays either from the Siwalik beds, or from the alluvium itself.

There is very little of interest in this borehole. The depth to which it was carried was insufficient to test the thickness of the alluvial deposits, and it ceased 200 feet above the level of the sea. No mention

[1] T. Login, Q. J. G. S., 1872, p. 198.

is made of any organic remains being found, but their occurrence could not be anticipated, as they occur but rarely in the alluvial formations of the Gangetic plain.

The borehole at Sabzal-ka-kot is only 4 miles from the base of the hills, and by far the greater portion of the beds traversed consist of sand and pebbles, clays being subordinate, although several beds have occurred.

Fossils in Indo-Gangetic alluvium.—The rarity of organic remains, especially in the older alluvial deposits, has already been noticed, but shells are occasionally found belonging to species now inhabiting the rivers and marshes of the country. An important discovery of mammalian remains was made about 1830 in some calcareous shoals of the Jumna.[1] The bones were chiefly found cemented together with substances of recent origin, such as fragments of weapons and boats, into a mass of concrete, chiefly formed of the kankar washed from the river's bank, but in two cases the skeleton of an elephant was found preserved in the clay. In one instance, in which the bones were clearly *in situ*, they were found 4½ feet above the highest flood mark, and 80 feet below the summit of the clay cliff formed by the river, and there appears no reason to doubt that all the specimens found were originally derived from the clay. The following species have been recognised[2]:—

Semnopithecus, sp.	*Sus*, sp.
Elephas namadicus.	*Bos* (*Bubalus*) *palæindicus*.
Mus, sp.	*Bos*, sp.
Hippopotamus (*Tetraprotodon*) *palæindicus*.	*Antilope*, sp.
Equus, sp.	*Cervus*, sp.
	Fish and crocodile bones.

Three of the species (all that have hitherto been specifically identified) are found in the Narbada alluvium also, whilst the only genus not now found wild in India is the *Hippopotamus*, which belongs, however, to the same sub-genus as the living African animal. The evidence is not sufficient to justify any decided conclusions, except that the Jumna clays must have been deposited in the same post-tertiary epoch as the Narbada alluvium; but so far as the specific identifications go, they tend to indicate that the Jumna fossils are newer than the Narbada remains, as the extinct type, *Hexaprotodon*, and the foreign form, *Bos namadicus*, have not been recognised amongst the former.

[1] Sergeant E. Dean, J. A. S. B., IV, pp. 261, 495. See also Falconer, Q. J. G. S., 1865, p. 378; Pal. Mem., II, p. 640.

[2] Several are figured, J. A. S. B., II, Pl. xxv; and IV, Pl. xxxiii.

Some bones were also found in the Betwa river in Bundelkhand and on the Bugaoti between Mirzapur and Chunár,[1] but they have not been identified.

General surface features of the Indo-Gangetic plain.—To enter at length into the various peculiarities of land surface[2] which are found in different parts of the great plain of Northern India would be far beyond the scope of the present work. A brief account of the principal characters must suffice. The whole region may be roughly divided into five great tracts, each possessing marked peculiarities: these are, commencing to the eastward,—

1. The Brahmaputra valley in Assam.
2. The Delta of the Ganges and Brahmaputra.
3. The plains of Upper Bengal and the North-West Provinces.
4. The Panjáb.
5. The Lower Indus Valley and Delta.

Bhabar, Tarai, Bhangar, and Khadar.—These are four Hindi terms, applied in the Ganges valley to particular kinds of alluvial surface, which require notice, because they will be found freely used in many papers relating to the subject, and because, with perhaps one exception,[3] they have no precise equivalents in English.

Bhábar is the slope of gravel along the foot of the Himalayas. Compared with the slopes in the dry regions of Central Asia, Tibet, Turkestan, Persia, &c., the gravel deposits at the foot of the great Indian ranges are insignificant, the difference in height between the top and bottom of the slope nowhere exceeding 1,000 feet: Mohan at the base of the Himalayas, 24 miles from Sahâranpur, is 1,498 feet above the sea, or 591 above Sáharanpur. This difference is probably partly due to the much greater rainfall in India, and to streams being consequently able to carry away a much larger proportion of the detritus washed from the surface of the hills, partly also to the circumstance that the rocks in the lower regions of the hills are not subjected to the loosening effects of frost.

[1] J. A. S. B., IV, p. 571.

[2] The following papers may be consulted for fuller accounts:

For Assam—Mem. G. S. I., IV, p. 437; VII, p. (155).

For Lower Bengal and the delta—Mr. Fergusson's paper, Q. J. G. S., XIX, 1863, p. 321; also Colebrooke, As. Res., VII, p. 1; and Rennell, Phil. Trans., 1781, p. 78.

For the plains of Upper India—Rec. G. S. I., VI, p. 9; Sir P. Cautley, Ganges Canal; Falconer, Q. J. G. S., 1865, p. 377: Login, Q. J. G. S., 1872, p. 186.

For the Panjáb—the sketch of the Geology published in the *Gazetteer*.

[3] The exception is *khádar*, which corresponds to the English word *strath*. The English term is, however, local; its exact meaning is far from commonly known, and it is only used in hilly country.

Streams, issuing from the Himalayan ranges, lose a part, or the whole of their water, by percolation through the gravel in the *bhábar* region. The whole tract in its original condition is covered with high forest, in which the sál (*Shorea robusta*) prevails. At the base of the slope, much of the water which has percolated the gravel re-issues in the form of springs, the ground is marshy, and high grass replaces the forest. This tract is the *tarai*, a term not unfrequently applied to the whole forest-clad slope at the base of the Himalayas, known also as *morung* in Nepal.

The alluvial plain itself, in the North-West Provinces especially, is composed of *bhángar*, or high land, the flat of older alluvium now at a considerable elevation above the rivers which traverse it; and *khádar*, or low land, the low plain through which each river flows. The latter has evidently been cut out from the former by the streams; it is of variable width, and is annually flooded.

Bhur land.—In the Upper Provinces the high banks of the rivers are frequently capped by the hills of blown sand, known in the North-West Provinces as "bhúr." This is the extreme form of a rather important element in the formation of Indian river channels, and the same result in a less marked form may be traced in a rather sandy, raised bank, along the course of many large rivers down to the limits of tidal action in the deltas. In the lower parts of the river plains this bank, which is above the flood-level, and is usually selected for village-sites, intervenes between the river channel proper and the marshy ground liable to annual floods on each side, the communication between the two latter being kept up by numerous creeks. The origin of the *bhúr* land, or raised bank, is the following.. During many months of the year, and especially in the hot season, strong winds arise, frequently of a very local character, and sometimes apparently almost confined to the river channels, which, in the dry season, are plains of loose sand often 2 or 3 miles across and sometimes wider, the river occupying usually not more than a fourth of its bed. The wind on the Indus and Ganges frequently blows in nearly the same direction as the river channel. Such winds are especially prevalent about midday and in the afternoon, and their effect in transporting the sands of the river bed is so great, that the atmosphere becomes too thick for objects a few yards distant to be seen. All who have been in the habit of navigating Indian rivers must have noticed the prevalence of these sand storms; they are so marked that where large sand-banks exist to windward of the river, it is often impracticable for vessels to continue their course, except in the morning before the wind arises, or in the

evening, when the motion of the air has diminished. Much of the sand raised by the wind falls again in the bed of the river, but quantities must fall upon the banks in the immediate neighbourhood, where the deposit is retained by vegetation and gradually consolidated into a firm bank. It is only where the quantity of sand is greater that blown sand hills are formed. The original raising of the river bank to the flood-level is due to the deposition of silt in a manner which will be explained presently when treating of deltaic accumulations, but the elevation of the immediate neighbourhood of the river bed above the reach of the highest floods is probably due to the deposit of sand by the wind.

The Brahmaputra valley in Assam.—The Assam valley is a gigantic *khâdar* or strath, the greater portion being liable to flooding and consequently not in a habitable state. There are, however, here and there higher tracts, sometimes mere mounds rising a little above the general level, and sometimes small plains,[1] and these may be considered as representing the extensive *bhângar* of the Gangetic plain. Along the foot of the hills are gravel deposits, but they do not appear to be very extensive.

The quantity of silt carried down by the Brahmaputra is very great, far greater than in the Ganges. The comparative backwardness of the river valley, as shewn by the small amount of habitable land, is surprising, since it is evident that the river is occupied in rapidly raising its plain by deposits of silt, and the necessary inference is, that the alluvial plain of Assam, in its present form, is not only of later date than the Gangetic plain, but absolutely newer than many portions of the Ganges delta.[2] The difference may be due (1) to a depression of the lower part of the Brahmaputra valley in Assam; (2) to an elevation of the delta; or (3) to a great increase in the supply of water. The second theory is distinctly disproved by the general evidence of subsidence in the delta, and the third is improbable; the evidence is therefore rather in favour of the Brahmaputra valley in Assam having been an area of subsidence in a relatively late geological period. As will be shewn presently, there is some additional evidence in favour of this view within the delta itself.

The delta of the Ganges and Brahmaputra.—The limits of the actual delta, of course, correspond with the spots at which the rivers

[1] Mem. G. S. I., IV, p. 438. One of these plains is described by Major Godwin-Austen, J. A. S. B., 1875, XLIV, Pt. 2, p. 40.

[2] For a full discussion of this argument, see Fergusson, Q. J. G. S., 1863, pp., 330, &c. It should, however, be noticed that Mr. Fergusson was led by some published barometrical observations, now shewn to have been insufficient, to suppose the level of the Brahmaputra valley at Gauhati to be only about 100 feet above the sea, instead of 163, the maximum flood-level since determined by the Great Trigonometrical Survey.

commence to bifurcate and become distributaries. This spot is at present in the Ganges between Rájmahál and Murshidabad, and on the Brahmaputra opposite the south-east corner of the Gáro hills.

But for a considerable distance above the actual delta the rivers flow through a broad plain of low ground, a large area of which is liable to flooding, and consequently to the deposition of silt. The delta is, in fact, the natural continuation of the *khádar* or alluvial flat in the upper portion of the river's course, and this *khádar* becomes broader before it expands into the delta.

Mr. Fergusson's theory.—By far the best description of the Ganges delta, of the changes it is undergoing, and of the action of the rivers in raising the land by the deposition of silt, is that of Mr. Fergusson.[1] He has shewn that rivers oscillate in curves, the extent of which is directly proportional to the quantity of water flowing down the channel. Thus the oscillations of the Ganges where broadest (7,000 feet in the low season), between Monghyr and Rájmahál, average 9½ miles in length; where it contains less water, and is only half the breadth (3,500 feet), between Allahabad and Chunar, the oscillations are 3·7 miles long; in the Bhagirati (Bhagiruthee), where it averages 1,200 feet in breadth, the length of the oscillations is 1·5 miles; and in the Matabangah, where only 500 feet broad, the length of each oscillation becomes only half a mile.[2] The next point which he notices is well known, the tendency of rivers to raise their banks, but the explanation is partly novel. When the whole country is covered with water, moving rapidly towards the sea in the river channels, and stationary throughout the intervening marshes, the dead water of the marshes prevents the floods of the rivers from breaking out of the channels, and, by stopping the course of the silt-charged water along the edges of the creeks and streams, forces it to deposit the sediment it has in suspension. Hence gradually arises a system of river channels, traversing the country in many directions, between banks which are higher than the intervening flats, and these flats form persistent marshes, known in the Ganges delta as *jhils* or *bhils*.[3]

Each river frequently changes its precise course, the smallest alteration in its channel having an effect which is felt for many miles above and below, so that, just as the oscillations of a denuding stream produce a low alluvial flat between high banks, the curves of a depositing river gradually form a high alluvial flat, raised above the surrounding country.

[1] l. c.

[2] l. c., p. 324.

[3] The former term is Hindi; the latter, Bengali. A further stage in the process by which the bank of a river is raised above the surrounding country through the action of wind has already been explained, see p. 404.

In course of time, this raised tract is abandoned by the main river for the lower ground at the side, and the river bed is either filled up by silt, or, if near the sea, converted into a tidal creek.

According to Mr. Fergusson's data, rivers at a greater slope than about 6 inches in a mile cut away their banks; those with a lower slope deposit silt. The precise limit is not ascertained, and it should be recollected that under favourable conditions, as when issuing from hills, coarse materials are deposited at any part of a river's course, provided the slope of the channel diminishes. The approximate limit of silt deposit only applies to rivers running in an alluvial plain.

The present Bengal delta, therefore, comprises a large area in which the ground has been raised above the general flood-level, through having been traversed by the main branches of the Ganges in past times. Such is the case in the country north of Calcutta. The eastern part of the delta is more backward; the marshes or *jhils* are more extensive, and the banks of the streams less consolidated, and this is now the great depositing area. But large tracts of low country, such as the salt lake near Calcutta, are found in the western area also. The remarkable struggle which takes place between the Ganges and Brahmaputra, each tending, by raising the neighbourhood of its channel, to drive back the other, and to gain possession of a larger tract of delta, is most vividly told by Mr. Fergusson, but is too long for extract here. Mr. Fergusson refers many of the more modern changes in the delta to the upheaval of the Madupur jungle, a great tract running for 70 miles north from Dacca and consisting of *bhángar*, or old alluvium, above the general level. The upheaval of this tract, which is about 35 miles wide where broadest; and, on its well-defined western face, whence it slopes gradually to the eastward, 100 feet above the alluvial plain, had the effect, in Mr. Fergusson's opinion, of diverting the Brahmaputra to the eastward into the Sylhet *jhils*, where the silt of the river was deposited. The result was that scarcely any sediment found its way to the sea by the Megna, the great estuary of all the Sylhet rivers, and hence the sea-face of the delta to the eastward curves back in the form of a gulf. The gap was much greater at the commencement of the present century, but about that time the Brahmaputra having, by the deposit of silt, greatly raised the portion of the Sylhet *jhils*, into which it flowed, changed its course completely in the course of a few years, and, instead of flowing to the east of the Madupur jungle, cut out a new channel to the west of the raised tract. Since its change, of course, the Brahmaputra has been brought much nearer to the main stream of the Ganges, and the two rivers are now depositing silt so rapidly on the eastern sea-face

of the delta, that great changes are taking place, and new islands are rapidly forming, whilst the western portion of the deltaic coast line, through which but a small portion of the flood water of the great rivers finds its way to the sea, has undergone but little change since it was first surveyed in the last century.

In the sea outside the middle of the delta there is a singularly deep area, known and marked on charts as the "Swatch of no ground," in which the soundings, which are from 5 to 10 fathoms all around, change almost suddenly to 200 and even 300 fathoms. This remarkable depression runs north and south, and has been referred to a local sinking, but it appears more probable, as has been shewn by Mr. Fergusson, that the sediment is carried away from the spot, and deposition prevented, by the strong currents engendered by a meeting of the tides from the east and west coast of the Bay of Bengal. Mr. Fergusson also shews that, so long as the Bay of Bengal has preserved its present form,[1] the meeting of the tides must have favoured the formation of a spit of sand along the present position of the Sundarbans, as the lower portion of the Ganges delta is called, and that any great deposit of silt to seaward of the present line is impeded by the fine sediment being washed away by the tidal currents, and deposited in the deeper parts of the Bay.

The Madupur Jungle.—The chief point in the above series of theories to which exception may be taken is the question as to whether the Madupur jungle is really an area of elevation. This may be the case, but it is manifest that precisely the same deflection in the course of the river as is attributed to the elevation of the ground north of Dacca, may have been produced by the depression of the area now occupied by the Sylhet *jhils*, and such a depression appears more in accordance with our present knowledge of the delta. Enquiries into the ultimate cause of all the changes by which rivers are converted from denuding into depositing agents, or by which they are made to cut a channel at a lower level through the beds which they formerly deposited, are surrounded by so many difficulties, owing to the magnitude of the operations, and the small differences of level to which such great results are due, that it is not advisable hastily to conclude that either of the explanations above suggested is correct. That some change of level must have taken place since the alluvium now forming the Madupur area was deposited, seems clear, because the ground of the area is higher than the present valley

[1] This is probably not so old as pliocene, because such gigantic disturbance has taken place throughout the extra peninsular regions of India, inclusive of the Assam hills and Arakan, since the close of the Siwalik epoch, that the shape of the northern part of the Bay of Bengal may have changed greatly.

of the Brahmaputra to the north and west, or than the old valley leading to the Sylhet *jhils* to the eastward. There are three possible explanations: the Madupur jungle may have been raised; parts of the surrounding country may have been depressed; or thirdly, the alluvium of the Madupur area may have been deposited by some other river than the Brahmaputra. The last hypothesis appears unsatisfactory, for the Gangetic streams could not have crossed the low area to the westward, and it is improbable that the Sylhet streams, the Surma, &c., which are said to contain comparatively little silt, could have raised their plain to so considerable a height; moreover, they could only have reached the tract north of Dacca if the area now occupied by the Sylhet *jhils* was so much higher than it now is, as to be able to deflect their course to the northward. The only satisfactory explanation involves a partial and unequal change of level, either of depression or elevation.[1] It has already been noticed in the description of the Assam valley, that the singularly marshy condition of the surface of the river may be due to a late action of depression. Earthquakes are of common occurrence both in Assam and Sylhet, and they are frequently severe; and although it would be absurd to conclude, without further evidence, that they are caused by depressions of the surface, it is certain that they have accompanied such movements elsewhere. It does not appear, on the whole, impossible that both the Brahmaputra valley in Assam and the area of the Sylhet *jhils* have sunk in comparatively recent times; that the Madupur jungle has escaped the action of depression, and that this raised tract marks the original level of the Brahmaputra deposits. But it is equally possible, even admitting the depression of the Assam and Sylhet areas, that the tract north of Dacca has been slightly raised.[2] So far as the Madupur jungle alone is concerned, the presence of this and similar masses of *bhángar* land might be due to depression in the delta, and consequent denudation of the ground traversed by the rivers on their way to the deltaic area of depression, but, admitting that the highest level in the Madupur jungle is the ancient flood-level of the Brahmaputra plain, we have to account for the very small difference between the level in question and that of the Brahmaputra valley 200 miles farther up at Gauhati. We can scarcely suppose that all the old *bhángar* has

[1] It may be useful to call attention to the remarkable results of the earthquake of 1819, and its effects on the western portion of the Ran of Cutch, as an illustration of the manner in which a portion of an alluvial area may be elevated, whilst another tract is depressed, during a single series of earthquake shocks. There is some question, however, whether elevation really took place. It is usual to ascribe elevation and depression to the earthquake; perhaps it would be more correct to attribute the earthquake to the elevation or depression.

[2] Mem. G. S. I., IV, p. (440); VII, p (156).

been swept out of Assam, but if not, some rises of old alluvium should be left as high above the general level as the Madupur jungle is. As no such raised tracts exist, we are driven back again to a local depression of the Assam valley, or of parts of it.

On the western edge of the delta in Bengal there is a large area of older alluvium, the surface of which is slightly undulating, evidently in consequence of partial denudation of the surface. This tract, which is continuous with the alluvial area of the east coast, comprises the greater portion of the country to the westward of the Bhagirati and Hooghly, and probably owes its comparative elevation to the deposits from the More, Adjai, and Damúda rivers.

Plains of Upper Bengal and North-West Provinces.—The great plain of Northern India is the area of an alluvial deposit older than that of the delta, and the greater portion of the area is composed of *bhángar* land, through which the rivers cut their *khádar* valleys at a depth of from 50 to 200 feet below the general level. The *bhángar* surface, as a rule, is nearly flat, but is much cut up by ravines in the neighbourhood of the rivers.

The question as to whether the great rivers are, as a rule, raising their beds by a deposit of silt, or cutting their channels deeper, has been much discussed without leading to any definite conclusions. The abrupt scarps by which the *bhángar* is not unfrequently terminated, and the defined limits of the *khádar*, clearly prove that the latter has been at some time or other an area of denudation, but it is not easy to tell whether, at the present time, in any given stream, the tendency is to raise or lower the general *khádar* level. It is also by no means so evident, as might at first sight be supposed, whether the *bhángar* land generally is an area of denudation or of deposition, although this can, as a rule, be easily seen in each particular area: thus, between the Sutlej and Jumna, the minor hill streams from the lower ranges of the Himalayas must deposit sediment, for they cease within the area, whilst between the Jumna and the Ganges numerous streams rise in the *bhângar*, and they must be denuding agents. In the neighbourhood of the *khádar*, *bhángar* land is frequently cut into by ravines, which prove conclusively that the surface of the country is being washed away, but all such marks of rain-action cease at no great distance from the low ground, and the principal secondary streams, instead of running from the upland *bhángar* by the nearest route, at right angles, or nearly at right angles to the main river, usually pursue a nearly parallel course down the middle of each "doab"[1] or triangular area between each two principal streams.

[1] A Persian word, meaning two waters, and applied to the confluence of two rivers, as well as to the land intervening between them.

The longitudinal section of every river channel in the Gangetic plains, for some distance at all events after leaving the hills, would be found, if drawn accurately, to be slightly concave, the fall at the exit from the hills being greatest, and gradually diminishing. The result of this is, that so long as diminution takes place in the fall, and consequently in the velocity of the water, there must, when the river is carrying as much earthy matter as it can transport, be a continuous deposition of detritus; the coarsest particles, such as large pebbles and gravel, being first left behind, then fine gravel, then sand; but so long as the fall diminishes, there must be deposition and a gradual raising of the area flooded by the stream. In the larger rivers this is the case, if at all, to a minor extent, because there is, at all times, a considerable body of water in the river, and this is sufficient to remove from the channel during the drier months of the year, when little or no coarse detritus is brought down from the hills, the deposits of the rainy season, when the water is charged with the products of pluvial denudation. But the effect of the small streams, which dry up more or less for a great portion of the year, but which are converted into muddy torrents charged with coarse sediment during the heavy rains of the summer monsoon, is to raise the surface of each "doab," especially in the neighbourhood of the hills, and to produce floods from which finer sediment is deposited on the surface of the *bhángar* land. Whether the addition thus produced is, on the whole, greater than the wasting of the surface from rain, is a question which it is impossible to decide throughout a great part of the country.

The careful levels which have been taken throughout the North-West Provinces by the Great Trigonometrical Survey, and the far more accurate maps which are now in process of compilation, will probably, in the course of a few years, furnish definite data for a solution of this and other problems. One question, however, which presents itself, is the necessity of accounting for the rivers now cutting their channels at a level considerably below that of the alluvial *bhángar* flat, because this flat must, at all events in the neighbourhood of the *khádar*, have been deposited by streams from the same drainage area, at a period when the main river ran at a comparatively higher level. The change may be due to a general elevation of the upper Gangetic plain, or to a depression in the delta region. Of the former there is no evidence; of the latter, as shewn by the result of the Calcutta borehole, there is ample proof, and it is therefore quite possible that in early post-tertiary times, when the animals lived, of which remains are found in the Jumna alluvium, the area of the Ganges delta had been raised to a considerably higher level than it

occupies at the present time. Colonel Greenwood[1] has shewn that the deposit of silt in river valleys must take place backward; that the lowest portion of the slope must be first raised, and that the check thus given to the flow of water will cause silt to be deposited so as to raise the alluvial plain further up the course of the river, and if no change of level takes place, the gradual elevations of the Ganges delta by silt deposit will ultimately react on the higher portions of the valley until the rivers once more deposit alluvium on the high *bhángar* land, provided always that this has not been raised so much as to render the slope too great for the rivers to be depositing agents.

One point of interest has been explained by Mr. Fergusson in the paper so often mentioned. A glance at the map will shew that the Ganges from Allahabad to Rájmahál, and the Jumna from Delhi to Allahabad, flow close to the southern margin of the great alluvial plain. This is due to the enormous quantity of silt brought down by the Himalayan rivers, and the comparatively small supply furnished by those streams which debouch into the Ganges valley from the southward. The northern portion of the plain has consequently, been raised, and the main outlet of the whole forced to find its way as close to the hills of the southern margin as it can. During this process, the courses of the tributary rivers running from the northward have been driven westward, and, as Mr. Fergusson has shewn, the confluence of these tributaries with the main stream of the Ganges has been shifted upwards along the course of the main river, owing to the tendency of the streams to deposit silt in the neighbourhood of the delta.

The *bhábar* slope of gravel along the foot of the Himalayas, although evidently of comparatively recent formation, has frequently, to the eastward, been cut into terraces by the streams from the hills.[2] This is a necessary consequence of the streams cutting deeper channels in the rocks of the hilly ground. It is curious to note, however, that to the westward the *bhábar* is being raised instead of being cut through by streams. The difference is not improbably due to the much greater rainfall to the eastward, and to the streams being consequently able to carry away the

[1] Rain and Rivers, pp. 173, &c.

[2] Hooker, Himalayan Journals, I, p. 378, (larger edition). Dr. Hooker very naturally, writing nearly 30 years ago, when the study of river action was in its infancy, and when nearly all great deposits and all extensive denudations were supposed to be marine, attributed the gravel to a beach deposit, and the valleys to marine denudation. There has been since 1850, when Hooker wrote, a great revolution in those portions of geological dynamics which treat of the action, both destructive and constructive, of rivers and the sea, and especially in the views held, by English geologists at least, on the comparative amount of work done by the two agents.

gravel as they cut back their bed in the rock, whereas weaker streams are prevented from cutting back their channels by their inability to wash away the gravel they have already deposited. It may be, too, that from local causes the gravels to the westward are more easily percolated by water, and therefore streams, instead of carrying away the *bhabár* deposits, sink into them; but, judging from the enormous development of the gravel slopes in regions of small rainfall, it is more probable that the first hypothesis is correct.

Kalar or Reh.—In connection with the surface of the Upper Provinces another peculiar local feature requires explanation. Many tracts of land in the Indo-Gangetic alluvial plain are rendered worthless for cultivation by an efflorescence of salt, known in the North-West Provinces as *Reh*, and further west as *Kalar* (Kullar). The name *úsar*, meaning barren, is frequently applied to land thus affected. The salt varies in composition; it consists chiefly of sulphate of soda mixed with more or less common salt and carbonate of soda; it is only found in the drier parts of the country, being unknown in damper regions, such as Bengal.

The *úsar* plains have existed for an unknown time. Where the *reh* or *kalar* is abundant, the water in the upper stratum is impregnated to an extent that is productive of serious injury to the health of the population. To a greater or less extent, this pollution of the water near the surface is general throughout Upper India; yet in the worst *reh* tracts, sweet water is obtainable at depths below 60 to 80 feet.

It is consequently clear that the impregnation of the soil is superficial, and as the upper deposits are demonstrably of fresh-water formation, they must originally have been comparatively free from impurities. Still all soils contain some salt, and all the water draining from soils is impregnated to a certain extent. The salts forming *reh* or *kalar* appear to be the refuse products, and to consist of such substances resulting from the various processes involved in the decomposition of rock, or of detritus derived from rock, and the formation of soil, as are not assimilated by plants. Unless these salts are removed, they must accumulate, and the natural process of purification is evidently by percolation-drainage, so long as pure rain water, running through the soil, carries off any injurious excess of the rejected salts. If the amount of water percolating the soil be sufficient, and thorough drainage exists, there will be a constant dilution and renewal of the subsoil water; but if the quantity of water reaching the subsoil is no more than can be dissipated by evaporation, during the dry season, salts will accumulate in such subsoil water, and as this water is brought to the surface by

capillary action, and evaporated, the salts held in solution will be left as an efflorescence on the surface of the ground.

That the composition of *reh* does not differ greatly from that of the salts produced by the decomposition of such rocks as have contributed by their disintegration to the formation of the alluvial plains of India is shewn by the composition of the river water[1] running from the Himalayas, the mountains from which the detritus now forming the plains of India was originally derived.

In the case of Upper India it is easy to understand how the subversion of the natural conditions necessary for cultivation has been established, and it is by no means improbable that a similar process has, in other parts of the world, changed countries, once fertile and populous, into barren deserts. The whole country is treeless; for a great part of the year a scorching sun and a parching wind dry up the moisture in the ground, rendering it hard and impervious to water; when the rains of the monsoon season fall, a large proportion of the water runs off the surface, and the earth is unable to absorb more than a portion of what remains. Thus a great part is evaporated without penetrating the ground; the little that does percolate through cracks, and in a zig-zag way, through the more porous layers, to the upper water stratum, is no more than sufficient to replace what has been dissipated by evaporation, fed by capillary action.

This more or less complete want of water circulation in the subsoil must have been gradually producing its effects in Upper India throughout many generations. The natural process is so slow, that it would escape notice, were it not that from time to time larger tracts of land become barren. A disturbing cause has, however, been introduced in the form of great irrigation canals. Their immediate effect is to raise the level of the *reh*-polluted subsoil water, and thus to produce a great increase of evaporation, with the natural result of more *reh* being left on the surface, and more land being thrown out of cultivation. This effect of the canals is evident, and an obvious check upon it would be to keep the irrigation channels at a considerable depth below the surface of the ground. Such a plan, however, involves fresh engineering difficulties, and only meets one of the objections to the present form of irrigation. It is impossible to enter at length into the subject here, but it may be stated that, as all canal water contains salts in solution, whilst rain-

[1] In several analysis of river and canal water from the Ganges and Jumna, the proportion of sulphate of soda varied from 0. 0914 to 0. 4325 part in 10,000; chloride of sodium from 0. 0023 to 0·15 part. The proportion of the two to each other is similar to that found in reh. See Sel. Rec. Govt. India, D. P. W., No. XLII, 1861, pp. 47, &c.

water contains none, the only change in conditions, so far as the concentration of salts in the soil is concerned, by the addition of canal irrigation, unless facilities for drainage of the subsoil water are also provided, must be the addition of all the refuse salts contained in the canal water to those which would be produced on the surface by the simple action of rain and evaporation.

Salt wells.—South and west of Delhi and west of Agra, brine is obtained in places from wells in the alluvium. No particulars have been recorded which explain the occurrence of salt in these localities. The case is similar to that already mentioned in the Púrna valley in Berar. The distribution of the salt-producing ground appears irregular, and this is in favour of the salt being derived from springs in the rock beneath the alluvium.

The Panjab.—The plains intersected by the five great rivers which combine to form the lower Indus are not, as a rule, simply divided into *bhángar* and *khádar*, like the plains of the North-West Provinces. The fall in the Panjáb rivers is much more rapid, and their tendency to desert their channels and to take a new course is much greater; in fact, a great portion of the Panjáb is evidently composed of recent deposits, and is geologically very much in the condition of Upper Assam. The reason why the Panjáb plains are deserts instead of marshes is, that the area over which the water can spread is much greater, whilst the average rainfall is far less. In the Western Panjáb, the barren region, the annual fall of rain only amounts to from 6 to 8 inches, whereas in Assam it is from 66 to over 100.

Owing probably to the greater fall in the Panjáb rivers, their deposits are very sandy, and this character tends to diminish the pluvial denudation of the surface by allowing the water to sink into the soil. The action of winds upon the sand of the river, the formation of bhúr land, and the elevation of the ground in the neighbourhood of the river banks above the intervening tracts, through the deposition of blown sand, are exhibited in the Panjáb to a greater extent than in the Gangetic plain.

To the south-east the limits of the Panjáb alluvium are difficult to trace, owing to the manner in which both alluvium and rock are concealed by blown sand. The same is the case throughout the eastern margin of the Indus alluvial plain in Sind.

Ancient changes in the course of the Panjab rivers.—The ancient geography of the Panjáb is far better known than that of most parts of India, partly because the civilisation of North-Western India is older than that of other parts of the country, but still more because of

the accurate descriptions given by Greek writers of the Indian campaigns of Alexander the Great. It is consequently possible to form some idea of the principal alterations which have taken place in the course of the last 2,000 years, in the channels of the great Panjáb rivers. Unfortunately, our best guide fails us at the most critical point. Alexander never penetrated to the eastward beyond the land of the five rivers, and there is but little except vague tradition to tell whether the present tributaries of the Indus have ever flowed into the Ganges, or, *vice versâ*, those of the Ganges into the Indus. Yet it is certain that in no part of the great Indo-Gangetic plain have more important changes taken place since the dawn of history than in the neighbourhood of the watershed between the Indus and Ganges.

The lost river of the Indian desert.—The traditions of the Hindus point to a time when a great and sacred river, the Sarasváti, ran in the extreme east of the present Panjáb, between the Sutlej and the Jumna. The modern Sarasváti is an unimportant stream, fed by small tributaries from the outer Himalayan ranges, deriving none of its water from snows, becoming nearly dry in the hot season, and losing itself in the Rajpútána desert. According to some traditions,[2] this river formerly followed an independent course through the desert to the sea; and it is a curious fact that, on some maps, a stream, bearing the name of Sarasváti, is shewn running into the smaller division of the Ran at the head of the Gulf of Cutch. It is doubtful, however, whether there is any belt of country between the Arvali range and the Eastern Nara at a sufficiently low level to have permitted a river to run through Western Rajpútána from the Eastern Panjáb to the Ran, and another view, which is certainly supported by much stronger evidence, is, that the Sarasváti formerly joined the Sutlej, and that this pursued an independent course to the sea, under various names, of which the best known are Hakra, Sotra, and Wahind. The course of the lower portion of this old river coincides with the Eastern Nara in Sind,[3] and the upper part ran through a portion of the desert south-east of Baháwalpur,

[1] Cunningham, Ancient Geography of India, p. 220.

[2] Rogers, Q. J. G. S., 1870, p. 124. For further information on this interesting subject, which it is impossible to treat at length here, see Cunningham's Ancient Geography of India, l. c. Fergusson, Q. J. G. S., 1863, p. 348; and a very interesting, but anonymous, paper entitled "Notes on the lost river of the Indian desert," Calcutta Review, 1874, No. CXVII, p. 1.

[3] This must be considered as doubtful. The Eastern Nara runs through a series of broad marshes, and if a great river ever, in recent times, followed the course of the Nara, it is very singular that these marshes were not filled up to a greater extent by alluvial deposits.

where numerous mounds and other relics of old cities remain to attest that the country was once far better watered than it now is. It is an indubitable matter of history that the Beas (Biyas or Vipasa, the Hyphasis of the Greeks) formerly did not join the Sutlej, but pursued a distinct course to the Indus, and the union of the Sutlej with the Beas is very probably due to the former river now running more to the westward than it did.

The diminution in the volume of the Sarasváti has been attributed to various causes, a decrease in the rainfall amongst others, and especially to the destruction of forest on the lower slopes of the Himalayas. The latter has very probably produced a considerable decrease in the quantity of water running down the river during the dry season, but it is not improbable that Mr. Fergusson's suggestion[1] is correct, and that owing to the Sarasváti having raised its channel, whilst the Jumna has cut down its *khádar*, the water which formerly supplied the former river now runs into the latter.

The Lower Indus Valley and Delta.—The surface of the Indus alluvium in Upper Sind differs but little from that of the Panjáb; a considerable portion of the area is annually flooded, and the whole drainage of a great river being here, as in Assam, confined to a comparatively narrow tract, some permanent marshes of large size exist. The two most important marshy tracts are along the western edge of the valley from near Jacobabad to the Manchhar lake (a large *jhíl*) near Sehwán, and along the eastern edge from Khyrpur to below Umarkot. The latter is the channel considered by some the ancient course of the Sutlej. In the neighbourhood of the Indus the ground is rather higher, having evidently been raised by the deposit of silt, aided doubtless by the action of the wind on the sands of the river-bed.

Along the edge of the Khirthar range west of Sind, there is a well-marked *bhábar* slope of gravel, but, except where rivers run out of the range, the breadth of the slope seldom exceeds 1 to 2 miles. This gravel slope is absolutely barren, and, like other features in Sind geology, is more conspicuous on account of its barrenness.

There is one singular feature in the Indus Valley, to which nothing parallel is to be found in the Gangetic area. The river between Sukkur and Rohri has cut its way through a low range of limestone hills, surrounded on all sides by alluvial deposits; even to the south-east, where the limestone disappears beneath sandhills, the Eastern Nara, fed by the flood waters of the Indus, traverses an alluvial tract eastward of the hills. In fact, the circumstance that the flood waters of the Indus, both to the east and west, traverse plains at a lower level than the river-bed,

[1] l. c., p. 348.

is shewn by the course of the canals, and great fears have been entertained that the Indus may desert its present channel, and break out to the westward, through the plain in which Jacobabad is built, into the line of marshes already mentioned. The curious features of the tract are not even confined to the present river-course, for at Arur, 4 miles south-west of Rohri, there is another gap in the limestone range, said, on what is believed to be good historical evidence, to have been the bed of the river rather more than nine centuries ago. At that time the main stream is supposed to have traversed Sind considerably to the east of its present course; it passed by the old city of Brahminabad, 60 miles north-east of Hyderábád,[1] and then probably ran southward by the Purán, an old river-bed still existing, to the Kori creek, which was the principal mouth of the river. The Indus is said to have deserted its old bed at Arur or Alor for its present channel between Sukkur and Rohri, in consequence of an earthquake about A.D. 962; and as Brahminabad was also, in all probability, destroyed by an earthquake[2] at some period prior to A.D. 1020, it is not impossible that the two events were due to the same cause. The Indus is said to have deserted Brahminabad at the time when the city was destroyed. All the details preserved, however, are so much mixed up with mythical incidents, that but little dependence can be placed upon them, and nearly all the circumstances mentioned are more or less open to dispute. It is questioned, for instance, whether Arur was ever situated on the Indus, and it is contended that Bakkar, a fortress on an island in the river opposite Rohri, and consequently in the channel now cut through the limestone range, existed before the ninth century. Certainly, the channel through the hills at Arur is very narrow, and it is possible that it was never traversed by the main stream of the river, though the configuration of the ground supports the hypothesis that some stream has cut through the hills at the spot. Again, it is contended that Sehwán, the ancient Sindomána, was always on the Indus, and that consequently the main stream of the river must have run in ancient times where it flows now. But, on the other hand, Alexander is said to have left the river, and marched to the neighbourhood of Larkhana, and thence to Sehwán, from which place he "marched back to the river."[3] It may be fairly concluded that important changes have taken place in the course of the river, without feeling certain that the precise nature of these changes has been correctly ascertained.

The accumulation of fluviatile deposits in the Indus plain, and the consequent elevation of the surface, is well seen in the neighbourhood of

[1] Cunningham's Ancient Geography, I, p. 257, 264, &c.;—Sind Gazetteer, pp. 23, 116, 123.
[2] Bellasis, Jour. Bombay, Br. R. A. S., V, pp. 413, 467.
[3] Arrian, Anabasis, VI, 16.

Umarkot, where, as has already been mentioned, the flood water from the Nara trickles through the sand-hills forming the limit of the Indus alluvium, and fills large hollows between the ridges of sand. The level of the bottom of these hollows must have been, in all probability, at least as high as the general surface of the Indus plain at no distant date.

During the floods, water leaves the Indus and its tributary, the Sutlej, as far up as Baháwalpur, and flows southward by the Eastern Nara, which must be regarded as a distributary, although its waters now seldom reach the sea. The true head of the delta, however, is generally considered to be a little above Hyderábád, where the Phuleli stream leaves the river.[1] The channels of the delta frequently change, more frequently perhaps than in the case of the Ganges. The sea-face is, in all probability, determined by marine currents, and it is improbable that any great change is likely to take place through the deposit of sediment.

The eastern part of the Indus delta now receives but little water from the river. It is said that a large area of country in the neighbourhood of the Kori mouth was depressed during the earthquake of 1819,[2] and that the great size of the Kori creek is due to the depression. A very large area north-west of the Kori creek is covered with salt, sometimes a foot or even more in thickness, deposited from sea water.

In the neighbourhood of the sea the soil is usually argillaceous and firm, but, in the upper part of the delta, the whole surface is composed of loose micaceous sand with but little clay, and the rivers consequently have unusual facilities for changing their channels. The littoral portion of the delta is so low, that a broad tract of country is always overflowed at spring tides, whilst the bottom of the sea in the neighbourhood of the coast is so shallow, and the slope outwards so gradual, that large vessels cannot, in many places, come within sight of the land. A tract of country of variable width, but in places several miles broad, along

[1] A very good description of the Indus delta has been given by Lieutenant T. G. Carless, Indian Navy (Selections from the Records of the Bombay Government, XVII, pp. 461-500). See also a memoir by Assistant Surgeon J. F. Heddle, ibid, p. 403. Lieutenant Carless' paper is also published in the Journal of the Royal Geographical Society, Vol. VIII, p. 328. For the ancient changes in the delta of the Indus, see also Cunningham's Ancient Geography, p. 283, &c.

[2] It is stated by Carless (Selections, Records, Bombay Government, XVII, p. 500) that the alluvial formations exposed on the bank of the Kori creek opposite Kotasir are, with the exception of the uppermost layers, broken up in confused masses, and inclined to the horizon at an angle of 30 or 40 degrees. The disturbance is attributed to the earthquake. It would be well, however, that the spot should be examined by an experienced geologist, the vagaries of oblique lamination in sands and silts, deposited by the strong currents of an estuary, being very likely to mislead any one unaccustomed to the peculiar appearance of these deposits.

the sea-face of the delta, is annually flooded by the rise of the river, the water being kept higher than it would otherwise be by the influence of the south-west monsoon.

The Ran of Cutch.—Reference was made a few pages back to the Ran (Runn) of Cutch, and it was pointed out that this tract of country is evidently an old marine gulf now silted up. A brief description of the area and its peculiarities may, however, be well added to the account of the Indus delta, which it adjoins to the eastward.

The Ran[1] consists of an immense marshy salt plain, scarcely above the sea-level, and stretching for 200 miles from east to west, and in places nearly 100 from north to south. From the south-eastern extremity a low alluvial tract, dividing Ahmedabad from Kattywar, and including an extensive brackish water marsh called the Nal, connects the Ran with the head of the Gulf of Cambay. A very trifling depression, probably not amounting to 50 feet, would convert Kattywar into an island, and even a smaller amount of sinking would suffice to isolate Cutch completely; indeed, it is now an island during the prevalence of the south-west monsoon, when the sea, raised by the wind, dams back the water brought into the Ran by the various rivers which drain into the flat from Rajpútána, Guzerat, and Cutch, in the same manner as the level of the creeks is raised in the Indus delta. At this time portions of the Ran are 7 feet under water, but the average depth does not exceed 5 feet. The inundation lasts from July to the end of November, and portions of the surface, especially a tract to the westward near Sindri, depressed by the earthquake of 1819, are constantly covered with water. Below this water there is, in places, a bed of salt, sometimes as much as 3 to 4 feet in thickness.

There can be little doubt that the Ran was a gulf of the sea within recent times; not only do the traditions of the country all agree with this view,[2] but the present condition of the surface, an immense flat of

[1] For a fuller description of the portion north of Cutch by Mr. Wynne, see Mem. G. S. I., IX, p. 14. See also Burnes, Travels in Bokhara, I, p. 316; Grant, Geological Transactions, Ser. 2, V, p. 318; Frere, Jour. R. Geog. Soc., XL, p. 181; Rogers, Q. J. G. S., 1870, p. 118.

[2] There is some historical evidence also. When Alexander the Great sailed down the Indus, he passed through the great eastern branch, then the main stream of the river, but now dry, to the Kori mouth. Near this mouth, he came to a great lake (Arrian, Anabasis, VI, 20). Mention is also made of a great lake-like expanse of water in this direction by some Mahammadan historians (Elliot, History of India, I, p. 125). These notices are taken from the anonymous paper already quoted in the Calcutta Review for 1874, CXVII, p. 18. Sir B. Frere also states, on apparently good traditional evidence, that Verawow, in Nagar Parkar, north-east of the Ran, was a seaport from 500 to 800 years since (Jour. R. G. S., XL, p. 195). No mention of any sea north of Cutch appears to have been made by the Chinese travellers of the seventh century (Cunningham, Ancient Geography of India, I, p. 302).

sandy mud, can only be explained by supposing that the tract is the site of an inlet, now silted up. The barren condition of the surface is due to flooding by salt water at one season, and hot dry weather at other times; the soil is consequently too salt to support even the vegetation, such as mangroves, which will grow in ordinary sea water. Unless further depression takes place, the surface must be gradually raised by the silt brought in by rivers, and the tracts which support vegetation must extend.

The depression of an area of 2,000 square miles around the fort of Sindri in the western part of the Ran, and the elevation of a tract, said to be 50 miles in length, and in places 16 miles across, at the time of the great earthquake of 1819, have been described so often,[1] that it appears unnecessary to repeat the account here. In this case the circumstance which enabled the changes of level to be accurately estimated was the very remarkable fact that the whole of the tract affected was very nearly at the sea-level, and so close to the sea, that it was flooded immediately. A further depression is said to have taken place in 1845 in the same neighbourhood.[2]

At first the effects of the depression in 1819 was to produce a great sheet of water, navigable by boats of some size; but this has gradually silted up, and Mr. Wynne, on visiting the ruins of Sindri in January 1869, found that the greater portion had been filled up to nearly the level of the Ran, and that but a small shallow pool remained around Sindri itself.

[1] An account is given in Lyell's Principles, Ed. 1868, II, pp. 97-104, and has been copied into many text books. For a very full description by Mr. Wynne, see Mem. G. S. I., IX, pp. 29-47. Mr. Wynne doubts whether the "Allah Bund," the supposed elevated tract, was really raised, and suggests, with much probability, that the appearance of elevation was due to the depression of the ground around Sindri, south of the "Allah Bund."

[2] Nelson, Q. J. G. S., 1846, p. 103. Before quitting the subject of the great alluvial region of Northern India, it may be as well to point out that by far the greater portion of the earthquakes, and especially of the more severe shocks felt in India, occur in the immediate neighbourhood of the Indo-Gangetic plain, and especially near the deltas of the great rivers. It is a subject worthy of further enquiry how far the earthquakes are connected with the pressure caused by the constant increase in the alluvial deposits, and the repeated recurrence of depressions. The earthquakes are, as a rule, felt much more severely on the rocky ground around the alluvial plain, than in the plain itself: when depression takes place, as in the case of Sindri in the Ran, the shock may be but slightly felt at the locality principally affected, although towns in Cutch, on rocky ground, at a distance of several miles, are thrown down; but this is in accordance with well-known laws.

CHAPTER XVIII.

PENINSULAR AREA.

POST-TERTIARY AND RECENT FORMATIONS—*continued*.

Alluvium of the East Coast — Estuarine shells in the alluvium — Alluvium of the West Coast of India — Bombay — Guzerat — Kattywar and Cutch — Littoral concrete, shelly grits of Bombay, Kattywar, &c. — Lake deposits — Soils — Red soil — Black soil, cotton soil or regur — Distribution — Origin — Peat — Blown sand — Indian desert — Other desert tracts — Sand denudation and striæ on rocks — Pot-holes in rivers — Prehistoric human implements — Stone — Palæolithic — Flakes or stone knives, and cores — Neolithic — Copper, silver, and bronze implements — Iron.

Alluvium of the East Coast.—Throughout the east coast of the Peninsula from the delta of the Ganges to the neighbourhood of Cape Comorin, with the exception of a few miles near Vizagapatam, there is a broad belt of alluvial deposits,[1] varying greatly in breadth, but nowhere exceeding about 50 miles. In places the hills approach the sea, leaving only a comparatively narrow belt of sandy foreshore, as south of the Chilka lake in Orissa, and again near Pondicherry, whilst near the mouths of the great rivers Máhánadi, Godávari, Krishna, Cauvery, &c., broad alluvial plains extend for many miles, and owing to the quantity of sediment deposited, there is actually a slight projection beyond the general coast line, although the strong currents, which sweep up and down the coast, prevent the rivers from extending their deltas seaward to any great extent.

There can be no reasonable doubt that the alluvial belt mentioned owes its existence, in a great measure, to the large quantity of detritus brought down by the rivers, for, as has been shewn in the introductory chapter, nearly the whole drainage of the Indian Peninsula runs eastward. It is difficult to judge whether the deposits would alone suffice to protect the older rocks from marine action. Probably they would, but the fringe of alluvial formations has unquestionably been raised since its deposition, for marine shells are found, in several places, many feet above the present range of the tide. The sea now in many localities gains upon the land, portions of the coast being occasionally washed away; but this action appears to be local, and there is no evidence of general marine denudation along the coast line.

[1] For details, see Mem. G. S. I., p. 274; IV, p. (247), and X, p. 15; also Newbold, Jour. Roy. As. Soc., VIII, p. 248.

To the northward the east coast alluvium joins the older alluvial deposits on the western side of the Ganges delta, and the two resemble each other closely in mineral characters. The coast alluvium consists chiefly of clays, with kankar, and, near the hills, pisolitic nodules of iron peroxide, the latter being in places sufficiently abundant to render the deposit a kind of laterite gravel. Gravels and sand also occur, frequently more or less mixed with ferruginous concretions, and there is in many localities an apparent passage between the ferruginous gravel of the alluvium and the low-level form of laterite.

The surface of the coast alluvium is usually quite flat near the sea and in the river deltas, but towards the hills it is more uneven, and evidently, from being at a higher level, the surface has undergone a considerable amount of denudation. In places this older alluvium rests upon the low-level laterite, which has been shewn, by the occurrence of palæolithic implements, to be itself of post-tertiary age, but in other places, as already noticed, there is an apparent tendency to a passage between the two. This may, of course, be due to the more gravelly forms of the laterite being washed down and re-arranged with the alluvial deposits.

Estuarine shells in the alluvium.—At Madras and Pondicherry, in several cases, shells belonging to recent species have been found in wells at depths of from 5 to 20 feet beneath the surface, or considerably above the present sea-level. The shells, as a rule, are estuarine forms, such as now live in the creeks and backwaters of the coast,[1] but in several cases true marine species have been found. About Madras the shells are found in beds of clay, and the following boring gives the whole thickness of the alluvial deposits[2]:—

	Ft.	In.
Sand and clay	3	0
Light-coloured sand and clay	1	0
Stiff clay	3	6
River sand	5	6
Black clay mixed with sand and shells	20	0
Blue clay with sand and lime and pieces of ironstone	12	6
Granite and quartz rubble	0	6
Clay and gravel mixed with broken granite, quartz, mica, &c.	9	0
TOTAL	55	0

[1] The following are the most characteristic species. They are seldom, if ever, found in the open sea, but they are always met with in backwaters, and at the mouths of rivers, and many of them occur in creeks of deltas near the sea.

Potamides telescopium.	*Cytherea casta.*
P. fluviatilis.	*C. meretrix.*
Arca granosa.	*Ostrea*, a large species.

[2] Newbold, l. c.

The site of this boring was at the Inland Custom-house, three-quarters of a mile from the sea. Beneath the depth mentioned crystalline rocks occurred. It is probable that the alluvium is in most places thicker than at Madras, but nothing more has been ascertained on this head. The subfossil shells near Madras are so abundant in places that they have been collected for burning into lime.

Farther south also, near Porto Novo, in the lower valley of the Vellaur,[1] a bed of estuarine shells is found above the present flood-level of the river, and consequently at a considerable height above the sea. Similar deposits of shells have also been noticed near Cuddalore and Tanjore.[2]

Another place where estuarine shells have been observed is close to the Chilka lake in Southern Orissa. The forms found were *Cytherea casta* and *Arca granosa*, and the deposit containing the shells is now at an elevation of from 20 to 30 feet above the level of the highest tides.

Alluvium of the west coast of India.—The differences in physical character between the east and west coast of India have already been noticed. Along the western shore of the Peninsula there is no such continuous plain of alluvium as on the east coast; the ground between the Sahyádri range and the sea, where not hilly, consists generally of a gentle slope towards the coast, composed of rock, covered in many places by laterite. The coast itself is rocky in parts, and the alluvial deposits are chiefly confined to the neighbourhood of the small streams, which run from the Western Gháts to the sea, or of the backwaters or lagoons which have been cut off by banks of sand along the coast. The backwaters are of considerable extent in Travancore and Malabar, but they are wanting farther north and on the coast of the Bombay Presidency; the alluvial valleys between the hills are unimportant south of Bombay itself, although they gradually increase in extent to the northward.

Bombay.—Alluvial plains, evidently of comparatively recent formation, connect the hills of Bombay and Salsette Island, a few creeks alone remaining to shew the position of the marine channels which formerly existed. Farther north these plains gradually increase in extent, until they merge into the alluvial flat of Guzerat.

At Bombay the alluvial deposits[3] consist of blue and yellowish-brown clay; the former varies in thickness from a few inches to several feet, its upper surface being at present about a foot or two below high-water level; it is very salt, and contains small grains and nodules of kankar, and

[1] H. F. Blanford: Mem. G. S. I., IV, p. 192.
[2] King and Foote: ib., p. (254.)
[3] Buist: Trans. Bombay Geo. Soc., X, p. 181;—Carter: Jour. Bombay Br. R. A. S., IV, p. 204.

occasionally plates of gypsum; it is frequently penetrated by mangrove roots, which are usually riddled by *Teredo* borings, just as in the mud of tidal creeks, and at one spot large masses of oysters have been found in it. The yellowish-brown clay appears to be the older of the two deposits; its surface is frequently above the sea-level, it abounds in larger masses of kankar, and it has occasionally yielded estuarine shells, *Placuna, Ostrea,* &c. That these alluvial deposits are estuarine, and precisely similar to the mud now deposited in the creeks and backwaters of the coast, or on the shores of Bombay harbour, is shewn by the similarity of mineral character and by the organic remains, both vegetable and animal, found in the clay.

It is evident that Bombay harbour is the last remaining inlet out of many which formerly indented the Bombay coast, and that this harbour is gradually silting up and being converted into dry land. The process, however, is probably slow, and it may be ages before its progress is such as to affect the trade of Bombay, but, unless depression takes place in the area, or means are devised for checking the deposition of mud, there can be no question of the ultimate result. Except at Bombay, little has been recorded concerning the alluvium of the western coast south of Damán, and that little presents no features of interest.

Guzerat.—In the neighbourhood of the rivers Tapti and Narbada, which, unlike the other streams draining the Peninsula, flow to the west coast, there is, however, near the sea, a broad and fertile alluvial plain,[1] which, in some of its features, resembles the alluvium of the east coast. Commencing to the southward near Damán, this plain covers the greater portion of the Surat, Broach, and Ahmedabad districts, and continues as far as the Ran, where it joins the area of recent deposits connected with the Indus valley. Near Surat this plain is about 30 miles in breadth, and near Baroda it is 60 miles wide.

The alluvium of eastern Guzerat consists of brown clays, with kankar, resting upon sands and sandy clays, with occasional gravels. The surface is covered with black soil to the southward, though not in the district of Ahmedabad, and is frequently horizontal over considerable areas, but in parts of the country the ground is undulating, evidently in consequence of having been denuded by rain-action. The deposits appear to have been chiefly estuarine or marine, and have probably been raised, as on the east coast, but no fossils have been found. The Gulf of Cambay is said to be gradually silting up, and there can be very little doubt that it was formerly part of a broad inlet leading from the Ran, then an inland sea, to the ocean, and that the remainder of the inlet

[1] Mem. G. S. I., VI, p. (233);—Rec. G. S. I., I, p. 30; VIII, p. 49.

has been converted into the alluvial plains of Ahmedabad, Broach, Surat, and north-eastern Kattywar.

Kattywar and Cutch.—In North-Eastern Kattywar, on the borders of the Ran, there is a large alluvial tract[1] continuous with the alluvium of Ahmedabad, and similar in character. Between Kattywar and Ahmedabad, in the line of depression between the head of the Gulf of Cambay and the Ran, there still exists a large shallow lake of brackish water, called the Nal, about 20 miles in length and 3 or 4 broad. In the neighbourhood of this marsh, shells of a form of *Cerithium* (probably *Potamides telescopium* or *P. fluviatilis*) are found, shewing that estuarine conditions have prevailed at no distant period, and tending to confirm the probability that the depression between Kattywar and Ahmedabad is an old marine inlet, silted up in recent times. The distribution of black soil in the neighbourhood of the Nal will be noticed presently.

Along the south coast of Kattywar there is very little alluvium, its place being taken by a calcareous grit, with marine shells, which is evidently of late formation.[2] A glance at the map will shew that this coast is exposed to the full action of the currents, which sweep along the shores of the Peninsula, so that it is unlikely that any accumulation of sediment would take place. The north-western coast of Kattywar on the borders of the Gulf of Cutch does not appear to have been described by any geologist; there is probably a belt of alluvium, as there is throughout the coast-line of Cutch,[3] where this belt is from 3 to 10 miles broad, there being only one place where rocks come down to the shore. This is in the Gulf of Cutch. The alluvial plain of Cutch consists of a brown loam, resting upon mottled clay, with kankar and grains of quartz.

Littoral concrete: shelly grits of Bombay, Kattywar, &c.—An agglutinated calcareous shelly grit is found, a little raised above the sea-level, in several places on the west coast of India. This deposit, which is called "littoral concrete" by Dr. Buist,[4] consists of shells, corals, pebbles, and sand, cemented together more or less thoroughly by carbonate of lime, and sufficiently compact in places to be employed as an inferior kind of building stone. The best known locality is in Bombay island, where the shelly grit forms the flat ground of the Esplanade and part of the surface on which the fort was built; the same deposit is also

[1] Rogers: Q. J. C. S., 1870, p. 118.

[2] MS. notes by Mr. Theobald.

[3] Wynne: Mem. G. S. I., IX, p. 81.

[4] Trans. Bombay Geog. Soc., X, p. 179; see also Carter; Jour. Bom. Br. R. A. S., IV, p. 206.

found at Mahim and other places in the island, resting sometimes upon rock, but more often upon the blue alluvial clay, described a few pages back. The same formation is found to the southward at Malwán,[1] and northward here and there as far as Damán, where it was observed by Mr. Wynne, apparently in process of formation.[2] Near Balsár, a little north of Damán, the littoral concrete was observed to be stratified, the strata dipping at a low angle towards the sea.

In Western Kattywar the same formation is much more widely developed. It here assumes the character of an earthy calcareous grit; it is usually of a dark ashy colour, and contains marine shells and corals; occasionally it attains a thickness of 60 feet, and it rests unconformably on the denuded surface of the "Miliolite."[3] The fossils found in the calcareous grit, so far as is known, are all species now living on the neighbouring coast, but no thorough comparison has ever been made.

There can be very little doubt that the shelly calcareous grits of the Bombay and Kattywar coast are truly marine, not estuarine, and that they are the result of a littoral accumulation of the sand and pebbles found on the shore, together with marine shells and corals. The beds may have originally been sand spits or beach deposits, very little, if at all, above high-water mark, and consolidated by the cementing action of carbonate of lime after being raised. In any case there appears to be evidence of a rise in the land, trifling at Bombay, but greater in Kattywar.

Lake deposits.—Indications of local deposits, supposed to have been formed in lakes, have been noticed on the Nilgiri hills of Southern India[4] and in the Southern Máhratta country,[5] and have been supposed to indicate changes of level. No fossils have been found in these deposits, nor does the evidence in either case amount to clear proof of the former existence of lacustrine conditions, although the probabilities are in favour of this view.

Soils.—It would be beyond the scope of the present work to enter into the question of Indian soils. Consisting as they do of the surface of the ground altered by the action of the air and rain, by impregnation with organic matter and the results of agricultural processes, they necessarily vary with every difference in the underlying formation, whether it be one of the older rocks or of the more recent unconsolidated deposits. There are, however, two forms of superficial formations which have received repeated notice in Indian geological works, and to which a few remarks must be devoted, and one of the two, the

[1] Mem. G. S. I., XII, p. 243.
[2] Rec. G. S. I., I, p. 32.
[3] See p. 342.
[4] H. F. Blanford: Mem. G. S. I., I, p. 243.
[5] Foote: Mem. G. S. I., XII, p. 228.

regur or black soil, is a very remarkable substance. The red soil also requires notice, because it has been so frequently mentioned in geological treatises.

Soils might very well be classed into two great sub-divisions:—upland soil resulting from the decomposition of rock *in situ*,—and alluvial soil, due to the surface alteration of river and flood deposits.[1] It would of course be difficult, if not impossible, to draw an exact line between the two, for the alluvial soil, on the margin of every valley, passes by insensible gradations into the upland soil of the hill slopes. The soils of the great Indian river plains belong of course to the alluvial sub-division, whilst the soil found on the plateaus of the Deccan and the undulating country of Southern India is to a large extent due to the decomposition of rock *in situ*, although alluvial soil of one kind or another is found in all hollows, and occupies large areas in the river valleys. Both "black soil" and "red soil" occur in large quantities in both sub-divisions; but the fine alluvial soil of the Indo-Gangetic plain is very different from either of the forms of surface prevalent in the Peninsula. Where the surface of the Ganges valley has undergone

[1] The Indian Peninsula is so vast, and the variations in climate in different portions so great, that the ingredients of the soil are only one amongst many factors determining the agricultural products of the country. The other principal elements are temperature and rainfall. Very roughly indeed, India might be divided into three agricultural regions:

I. Extra-tropical India; the wheat region. This consists of the great plains of Northern India in which the rainfall is moderate or small, and the winter temperature comparatively low. The region almost corresponds with that lying north of the January isotherm of 65°. The principal grains are wheat and barley.

II.—The damper portions of tropical India, the rice country. This comprises all Bengal proper, and all the region north of the Krishna from the Bay of Bengal to the edge of the trap country in the Deccan, together with the coasts and delta lands of Southern India. The principal grain is rice.

III.—The drier parts of tropical India and all the black soil country; the millet region. Besides the whole Deccan trap area, with the exception of the western coast, this comprises all the black soil tracts of Southern India, and a very large portion of the undulating red soil country. The principal grains are jawári or cholam (*Holcus sorghum*) and bájri or kambú (*Holcus spica*).

Of course, these divisions are not clearly separated from each other. The important point in connexion with the geology is the fact that nowhere in the black soil regions, nor on any of the soils derived from the Deccan traps, except in a small strip of country, with a heavy rainfall, near the western coast, is rice the staple grain of the country. In the Central Provinces, especially in the neighbourhood of Nágpúr, the difference between the agriculture of the trap country, with fields of millet, pulses of several kinds, cotton, linseed, &c., produced without irrigation, and the cultivated area of the sandstone and metamorphic rocks, where little is seen growing, except rice and sugar irrigated from large tanks, is as marked as the distinction between the rocks themselves. The wild vegetation of the two formations is as different as the cultivated grains. The whole distinction is of course due to the difference in the soils derived from different rocks.

but little change from agriculture, and where it is not impregnated by organic matter, it consists of a very fine, light-coloured argillaceous loam, varying from pale grey to pale brown in colour, and becoming very hard when thoroughly dry.

Red soil.—The somewhat ferruginous soils common on the surface of many Indian rocks, and especially of the metamorphic formations, would probably never have attracted much attention but for the contrast they present in appearance to the black soil. They have only been noticed, as a rule, in papers relating to the western and southern portions of the Peninsula, the black soil country. The commonest form of red soil is a sandy clay, coloured red by iron peroxide, and either derived from the decomposition of rock *in situ* or from the same products of decomposition washed to a lower elevation by rain. The term "red soil" is, however, frequently used in a very vague sense, apparently to distinguish such soils as are not black, and hence many alluvial soils may be comprehended under the general term. In very many cases, too, the term "red soil" appears to have been applied in Southern India to thick alluvial beds of sand or sandy clays, which are in fact ordinary river or rain-wash deposits.

Black soil, cotton soil, or regur (regad).—The regur of Peninsular India,[1] called black soil from its colour, and cotton soil from its suitability to the cultivation of cotton, occupies the surface of a very large portion of the country, and Newbold considers that at least one-third of Southern India is covered by it. The name regur is a corruption of the Telugu *regada*, or of cognate words in affined languages.

Regur, in its most characteristic form, is a fine dark soil, which varies greatly in colour, in consistence, and in fertility, but preserves the constant characters of being highly argillaceous and somewhat calcareous, of becoming highly adhesive when wetted, (a fact of which any one who has to traverse a black soil country after a shower of rain

[1] The following are some of the principal writers who have described regur:

Christie: Edinburgh New Phil. Jour., VI, p. 119 (1829); VII, p. 50 (1829); Madras Jour. Lit. Sci., IV. p. 469 (1836).

Voysey: J. A. S. B., II, pp. 303, 397 (1833).

Newbold: Proc. Roy. Soc., IV, p. 54 (1838); J. A. S. B., XIII, p. 987 (1844); XIV, pp. 229, 270 (1845); Jour. Roy. As. Soc., VIII, p. 252 (1846).

Hislop: Jour. Bombay Br. R. A. S., V, p. 61 (1853).

Carter: Jour. Bombay Br. R. A. S., V, p. 329 (1854).

Theobald: Mem. G. S. I., II, p. 298 (1860); X, p. (229) (1873).

H. F. Blanford: Mem. G. S. I., IV, p. 183, (1862).

King and Foote: Mem. G. S. I., IV., p. (352) (1864).

Oldham: Rec. G. S. I., IV., p. 80 (1871).

Foote: Mem. G. S. I., XII, p. 251 (1876).

See also Mem. G. S. I., VI, p. (235) (1869); Rec. G. S. I., VIII, p. 50 (1875).

becomes fully aware,) and of expanding and contracting to an unusual extent under the respective influences of moisture and dryness. Hence in the dry season the surface is seamed with broad and deep cracks, often 5 or 6 inches across and several feet deep. Like all argillaceous soils, regur retains water, and consequently requires less irrigation than more sandy ground; indeed, as a rule, in the Western Deccan, Nágpúr, and Hyderábád, black soil is never irrigated at all. When dry, it usually breaks up into small fragments; on being moistened with water, it gives out an argillaceous odour. It is said to fuse, when strongly heated, into a glassy mass, but, as might be expected, this is not invariably the case, and is probably dependent on the proportions of iron and lime present.

The chemical composition of regur has not received much attention. From the few and partial analyses[1] which have been made, the proportions of iron, lime, and magnesia seem to vary, and there appears

[1] The following are the analyses. In the first, by Dr. Macleod, and published by Captain Newbold, Jour. Roy. As. Soc., VIII, p. 254, a complete analysis of a dried sample appears to have been made. In the other analyses by Mr. Tween, (Mem. G. S. I., IV, p. (361),) undried soil was used, and the component parts were only determined in the soluble portion In neither case is it stated how the analyses were made, nor which ingredients were determined by loss:—

Silica	48·2	The locality from which this soil was obtained is not stated.
Alumina	20·3	
Carbonate of lime	16·0	
Carbonate of magnesia	10·2	
Oxide of iron	1·0	
Water and extractive	4·3	
	100·0	

	A 1	A 2	B 1	B 2	C	D	E
Insoluble	62·7	47·61	62·8	63·7	68·61	57·91	61·80
Organic matter	9·2	8·4	9·	8·7	7·2	8·7	7·65
Water	8·4	7·6	8·2	6·5	9·4	9·9	7·35
Oxide of iron	11·	15·9	10·9	11·4	6·76	4·36	5·7
Alumina	7·5	8·6	7·6	8·4	5·81	8·75	7·67
Carbonate of lime	1·2	11·89	1·5	1·3	1·57	9·28	8·53
	100·	100·	100·	100·	99·35	98·90	98·70

"The residue in all consisted chiefly of magnesia and alkali; in A1, B1, and B2, there were traces of sulphuric acid.

"A and B were from near Seoni, C from Indore, D from Barwáni, and E from Burhanpur: (Seoni and Barwáni are in the Narbada valley, and Burhanpur in the Tapti).

"A1, A2, represent the surface soil and subsoil taken from the same locality, A1 being the surface, A2 from 5 feet below surface. The two marked B1, B2, are, in like manner, the soil and subsoil (3 feet deep) from one locality, while C, D, and E are the soils taken from only a few inches below the surface. B1 is considered the best quality of soil."

always to be a considerable quantity of organic matter combined. The black colour appears to be due either to the carbonaceous elements of the soil, or to organic salts of iron, but the tint varies much, being frequently brownish and sometimes grey.

Christie made some experiments to determine the absorbent power of regur. He first dried a portion at a temperature nearly sufficient to char paper; he then exposed to the atmosphere of a moderately damp apartment 2615·6 grains of the dried soil, and found after a few days that it had gained 147·1 grains. He then exposed the same sample to an atmosphere saturated with moisture, and found that the weight increased daily, till the end of a few weeks, when it was found to be 2828·4 grains. The soil had, therefore, gained 212·8 grains, or about 8 per cent.

As a rule, the purest beds of regur contain no pebbles, although this soil usually abounds in kankar. Fragments of chalcedony or zeolite are, however, often found in the black soil, where it is derived from the decomposition of basalt, and in Southern India regur occasionally contains debris of the metamorphic rocks, sandstone or limestone, on which it rests.

Where uncultivated, black soil plains usually support but few trees, and those, as a rule, of no great size, but the principal product is grass, commonly growing to a height of 3 to 4 feet, but sometimes considerably higher. The growth of grass on the uncultivated plains of India is, however, greatly promoted, and the trees injured or killed by the universal practice of burning the grass annually in the dry season, so that it is probable that, if left to themselves, the plains of black soil would support forest.

The fertility of this soil is so great, that some of the black soil plains are said to have produced crops for 2,000 years without manure, without having been left fallow, and without irrigation. On the other hand, some varieties of black soil, occurring near the coast of Southern India, are comparatively infertile.

The typical appearance is only presented by this soil near the surface of the ground; if the regur is more than about 6 to 10 feet deep, it usually passes down into brown clay with kankar. It is never, except where it has been carried down and rearranged as a stream deposit, met with at any depth beneath the surface.

Distribution.—The distribution of black soil in the Indian Peninsula is of some importance, because it affords a clue to the origin of the formation. Regur is found everywhere on the plains of the Deccan trap country, except in the neighbourhood of the coast. A very similar

soil is found locally in the basaltic Rájmahál hills, but, with this exception, nothing of the kind appears to be known in Bengal or the neighbouring provinces. In Southern India, however, tracts of black soil are found scattered throughout the valley of the Krishna, and occupying the lower plains and flats of Coimbatore, Madura, Salem, Tanjore, Ramnád, and Tinnevelly. There is but little on the Mysore plateau. Some occurs on portions of the coast plain on the eastern shore of the Peninsula, and the great alluvial flat of Surat and Broach in Eastern Guzerat consists of this soil. The soils of Ahmedabad are light-coloured, but regur occupies the surface of the depression lying between Ahmedabad and Kattywar, and connecting the head of the Gulf of Cambay with the Ran of Cutch.[1]

Origin.—In many cases there cannot be a question that regur is simply derived from basalt by surface decompositon, and it is not surprising that numerous observers, from Christie and Voysey to Carter and Theobald, should have contended, and should still contend, that all cotton soil is derived from disintegrated trap rocks. Throughout the immense Deccan trap area, the passage from decomposed basalt into regur may be seen in thousands of sections, and all the alluvial valleys, most of which contain black soil, are filled with deposits derived from the disintegration of basaltic rocks. More than this: over enormous areas the boundary of the trap is approximately the boundary of the black soil; where the latter is found beyond the trap boundary, volcanic rocks may very probably have existed formerly, and have disappeared through disintegration, or the soil has been washed down from the neighbouring trap hills. This is admirably seen around Nágpúr and Chánda in the Central Provinces; everywhere upon the trap regur occurs; a few miles to the eastward, upon the metamorphic rocks, it is never seen, except where there is reason to suppose it has been transported, as in the alluvial flats of rivers, like the Godávari, running from the trap country. Again, whilst nothing resembling regur is found in the metamorphic region of Bengal, Behar, Orissa, Chutia Nágpúr, Chhattísgarh, and the neighbouring provinces, soils undistinguishable from those of the Deccan traps are found in the basaltic Rájmahál hills, and a similar formation has also been observed in Pegu,[2] derived from the decomposition of basalt. It has been urged that basalt may have been more widely spread in Southern India than is now the case, and that, where none is now found, its disappearance is due to its having been converted, by disintegration, into regur.

[1] Rogers: Q. J. G. S., 1870, p. 118. | [2] Theobald: Mem. G. S. I., X, p. (229).

This view cannot, however, be conceded. In the first place, as was shewn by Newbold, basalt generally disintegrates into a reddish soil, quite different from regur in character. This reddish soil may be seen in places passing into regur, but, as a rule, the black soil is confined to the flatter ground at the bottom of the valleys, or on flat hill tops, the brown or red soil occupying the slopes. Again, the masses of black soil in the valleys of the Godávari and Krishna might be due to the alluvial deposits having been derived from the trap rocks, through which both rivers flow in the upper part of their course, but hundreds of square miles in the basins of the Pennár, Palár, Cauvery, and other rivers still farther to the south are composed of precisely similar regur to that of the trap area. There is no reason for supposing that the Deccan trap ever extended to the valleys of the rivers named, nor can there be any reasonable doubt that the alluvial flats contained in these valleys are mainly formed from the detritus of metamorphic rocks.

Captain Newbold considered [1] all regur to be of subaqueous origin in India, and compared it to the deposits in tanks, and to the mud of the Nile. Mr. H. F. Blanford suggested [2] that the cotton soil of Trichinopoly had accumulated in lagoons or backwaters near the sea, and he shewed that in one place near Pondicherry typical regur was actually being formed in a nearly dry lagoon separated from the sea by a sand spit. Messrs. King and Foote, on the other hand, considered [3] it more probable that the Trichinopoly regur was a fresh-water deposit accumulated in marshes. It has since been shewn [4] that a complete passage takes place in the neighbourhood of Surat between the deposits formed in tidal estuaries and the regur of the surrounding country, and it appears probable that much of the black soil of Eastern Guzerat may have been originally a marine or estuarine (brackish water) formation. On the other hand, Hislop [5] objected to the theory of formation by deposition in water, and he appears to have been the first to suggest that regur may really be of subaërial origin and due to the impregnation of certain argillaceous soils by organic matter. This appears to be the most probable theory; there can be no doubt that some forms of regur originate from the decomposition of basalt *in situ*, others from the disintegration of other argillaceous rocks, whilst other varieties again were originally alluvial clays formed in river valleys, or deposited in fresh-water marshes, estuarine flats, or salt-water lagoons. The essential character of a dark colour appears due in all cases to the admixture of organic matter, and perhaps the presence of

[1] Jour. R. A. S., VIII, p. 256.
[2] Mem. G. S. I., IV, p. 191.
[3] Mem. G. S. I., IV, p. (357).
[4] Rec. G. S. I., VIII, p. 50.
[5] Jour. Bombay Br. R. A. S., V, p. 61.

a small quantity of iron. It is far from improbable that most of the black soil flats of India were at one time covered with luxuriant forest, for when the vegetation was not annually exposed to the effects of fire, the trees may have attained far greater dimensions than they do now. The increased dampness of the soil, the protection from denudation by rain, and the supply of decomposing vegetable matter may have contributed to the formation of themore fertile forms of regur. That the process of regur formation is purely superficial, and that it is due to surface action of a past time, is well seen in many of the regur plains with a slightly undulating contour. In such places, where the wash of rain has swept away the surface soil on the sides of hollows, the earth is brown; on the flats above, it is black, because the superficial layer has not been washed away; the black soil, however, washed from the sides of the hollows, has frequently accumulated towards the lower portion of them.

The abrupt termination of regur in places at the edge of the trap country is simply due to the change from an argillaceous soil to a sandy one. The basalt appears generally to decompose into a highly aluminous substance; the metamorphic rocks, on the other hand, produce sand to a large extent. At the same time, it should be stated that it is not quite clear why argillaceous deposits should have become regur in Southern India, whilst nothing of the kind is known in Bengal, except in the basaltic region of the Rájmahál hills. A dark-coloured soil certainly forms in the marshes of Eastern India; but it has not the character of regur, and no cotton soil has been noticed in the dense forests of Chutia Nágpúr and Bastar, nor, except on the surface of basalt, in the forest-clad plains of Burma. It is doubtful whether true regur occurs on the Malabar coast between Bombay and Cape Comorin, and the marshy soils on the top of the Sahyádri range do not form cotton soil. The black soil plains appear to be almost confined to those parts of India which have a moderate rainfall, not exceeding about 50 inches; but it is impossible to say whether this is a necessary condition.

It may then be stated that regur has been shewn on fairly trustworthy evidence to result from the impregnation of certain argillaceous formations with organic matter, but that the process which has taken place is imperfectly understood, and that some peculiarities in distribution yet require explanation.

Peat.—True peat forms in the hollows on the Nilgiris and some of the other mountains in Southern India, such as the Shivarais,[1] at

[1] Foote: Mem. G. S. I., XII, p. 252.

elevations above 4,000 feet, and its formation is due, as in temperate climates, to the growth and decomposition of a moss. In the marshes of the Gangetic delta an inferior kind of peat is also formed by the decomposition of various aquatic plants, and especially of wild rice.[1] The peat-like beds found so widely distributed in the neighbourhood of Calcutta at a little depth below the surface appear to be derived from the decomposition of forest vegetation.[2] A somewhat similar substance has been obtained from beneath a marsh in Oudh.[3]

Blown sand.—Sand drifted by the wind forms low hillocks on many parts of the Indian coast. Reference has already been made to the parallel ridges of sand-hills along the shore of Orissa.[4] A similar tract of blown sand is found north of Orissa in the Midnapur district, and southwards at intervals throughout the whole of the east coast.[5] The sand is, of course, derived from the sea-shore and blown up into ridges at right angles to the prevailing wind, with their longer slope to windward and a shorter and steeper surface to leeward. Smaller patches of sand are sometimes found on the banks of backwaters. The sand-hills frequently extend for 2 or 3 miles inland from the coast, and in such cases the inner ridges are covered with a peculiar vegetation, amongst which the cashew-nut tree (*Anacardium occidentale*) and a screw-pine (*Pandanus*) are conspicuous, and in some cases between the parallel ridges coinciding in direction with the coast the ground is flat, and even occasionally, as in parts of Midnapur, marshy. In the latter case, it is probable that a lagoon has existed, which has been gradually dried up, the origin of the lagoon being due to the formation of a sand spit outside it. As already noticed, the existence of several parallel sand ridges probably indicates a rise of land, each ridge coinciding with a former coast line.

On the Malabar coast, sand dunes are equally common, and, by accumulating on spits of sand, they contribute greatly to the formation of lagoons or backwaters.[6] In the northern portion of the western coast about Bombay no sand-hills have been noticed, probably because the detritus from the trap rocks does not form a suitable material, but further north again, in Surat and Broach,[7] in portions of Kattywar, and

1 J. A. S. B., XXIII, 1854, p. 400.

2 See p. 400.

3 Proc. A. S. B., 1865, p. 85.

4 Mem. G. S. I., I, p. 275.

5 Newbold: Jour. Roy. As. Soc., VIII, p. 268;—King and Foote: Mem. G. S. I., IV, p. (249);—Foote: ib., X, p. 12.

6 Newbold: Jour. Roy. As. Soc., VIII, p. 268.

7 Mem. G. S. I., VI, p. (235); IX, p. 82.

in Cutch, blown sand occupies more or less ground in many places in the neighbourhood of the shore.

Sand dunes in India are not confined to the sea-coast, but are frequently found on the banks of rivers. One example has already been mentioned, the Bhúr land of the Punjab,[1] and the accumulation of blown sand on river banks is of common occurrence on many of the peninsular rivers, such as the Godávari, Krishna, and Cauvery.[2] In some instances noticed by Newbold,[3] villages have been buried by the sand blown from the river beds during the dry season. In fact, the study of the action of the wind and its effect in transporting detritus of all kinds cannot be said to have received much attention hitherto, but in the drier parts of India the amount of dust and sand transported by the atmosphere must be very great.

Indian desert.—By far the most important accumulation of blown sand in India is, however, between Sind and Rájputána, in the tract known as the great Indian desert.[4] The name conveys a somewhat imperfect idea, because the region in question is neither absolutely barren nor uninhabited; it is covered with shrubs and bushes in general, and small trees are found in places, whilst villages are scattered throughout, and immense herds of camels, cattle, goats and sheep are pastured. The desert is, in fact, a great sandy tract without any streams of water, and a large portion of the surface consists of blown sand.

Besides the isolated sand-hills scattered over the region, there are some tracts, in particular, in which the whole area appears to consist of sand dunes. One of these tracts, known as the Thar (Thurr), extends along the edge of the Indus alluvium from the neighbourhood of the Ran of Cutch to north-east of Rohri, and probably farther still to the northward, towards Baháwalpur. This tract is about 60 miles across near Umarkot, and 50 miles east of Rohri. The sand-hills are arranged in regular parallel, or nearly parallel, ridges running north-east and south-west near Umarkot, whilst to the north their direction is from south-south-west to north-north-east. Farther south than Umarkot and near the Ran, the general direction of the sand ridges is said to be nearly east and west, and they are much higher than they are elsewhere, some having an elevation of as much as 400 or 500 feet.[5]

Another great tract of sand-hills more to the eastward extends north-north-east from the neighbourhood of the Ran along the western side of

[1] P. 404.
[2] King and Foote: Mem. G. S. I., IV, p. (249).
[3] Jour. Roy. As. Soc., VIII, p. 269.
[4] J. A. S. B., XLV, 1876, pt. 2, p. 86; Records G. S. I., X, p. 20.
[5] Sir H. B. E. Frere: Jour. Roy. Geog. Soc., 1870, vol. XL, p. 200.

the Luni river, towards Bikanir. Between Jodhpúr and Pokarn, this belt of sand dunes is about 40 miles broad. It is probably connected with the western tract by the east and west ridges already mentioned in the neighbourhood of the Ran. The sand-hills in the eastern tract are lower than to the westward, and they are not in such regular ridges.

Throughout the central portion of the desert around Bálmir and Jesalmir the ground is higher, and there are rocky hills. There is still a great quantity of drifted sand scattered over the surface, but sand-hills are few and of small size. The sandy region also extends to the eastward as far as the Arvali (Aravully or Aruvelly) range, and even beyond in places. To the northward blown sand is found throughout Baháwalpur and Bikanir as far as the neighbourhood of the Jumna.

The general direction of the sand-drift is evidently from south-west and south-south-west, the direction from which strong winds blow in the hot season, May, June, and July. At other times of the year the winds are light and variable, but in the months mentioned a steady breeze, sometimes becoming violent, sets in from the quarter named. It is a well-known fact, explained in all elementary works,[1] that sand or any other substance, moved along the surface by air or water, arranges itself in ridges at right angles to the current, with a lower slope towards the direction from which the moving power comes—to windward, in the case of air,—and a steeper slope in the opposite direction or to leeward. The "rippling" or current marking on the surface of sandstone, &c., is a familiar example, and so are the small ridges produced on the surface of dry sand by the wind. The long slope to windward varies in the angle of dip, the steep slope to leeward is that naturally assumed by the sand when blown over the crest of the ridge.

In general throughout the desert the sand-hills, whatever be their form, have a steep slope to the north-east, and a lower slope to the south-west, and the sand in many places, as west of Bálmir, accumulates in large quantities on the north-east or leeward side of the rocky hills. Even in the long parallel south-west and north-east ridges of the Thar, which are often from a quarter of a mile to half a mile across and extend for many miles, and in which there is no constant distinction between the slopes on the two sides, abrupt terminations with a steep slope to the north-east are frequently seen. It is evident that the enormous quantity of sand in the desert region is derived from the south-west, and that it has been transported by the strong winds of the hot season. Here two rather different questions arise: the source of the sand, and the reason

[1] See Lyell, Principles, (Ed. 1867) I, p. 516; De la Beche, Geological Observer, p. 59; Marsh, Man and Nature, pp. 471-483, &c.

why the great sand ridges of the Thar are parallel to the direction of the prevailing winds instead of at right angles to it.

It should be noted that many of the sand-hills are evidently of great antiquity; they often shew evidence of denudation from the action of rain, and in places they are worn into ravines several feet in depth. When the small rainfall of the desert region[1] is taken into consideration, it is evident that a long series of years must be required for ravines to be cut in the sand, since it is only in exceptionally heavy showers that any rain can run off so porous a surface. The great age of the sand-hills is also attested, though in a minor degree, by the evidence of the inhabitants.

It appears difficult to believe that all the sand found in the desert can have been derived from the Indus. The surface of the Ran at present is too muddy to furnish any large supply. The sand consists of well-rounded quartz grains mixed with smaller quantities of felspar and hornblend, and is undistinguishable from the sand of the sea-coast. That found in the bed of the Indus is also very similar in character. The most probable theory appears to be that the Ran of Cutch and the lower portion of the Indus valley have been, as has already been shewn to be probable on other grounds, occupied by the sea in post-tertiary times, and that the sand of the desert was derived from the shore. The most sandy tracts, as has also been shewn, are on the edge of the Indus valley, along the northern margin of the Ran, and along the depression of the Lúni valley, and these portions of the country were all probably situated on the coast. The form of the rocky hills around Bálmir and Jesalmir shews that they have been shaped by subaërial, not by marine, denudation, and it is probable that the central portion of the desert was land, whilst the Indus valley, the Ran, and the Lúni valley were occupied by sea.

The other difficulty, that of accounting for the direction of the sand ridges in the Thar, is greater. The most probable explanation appears to be that the hollows between the ridges are due to denudation by the wind, and that the tract was originally much more thickly covered by sand than it now is.[2]

The accumulation of sand in the desert region is evidently due to the low rainfall and to the consequent absence of streams, the effect being intensified by the accumulation of sand and the porous nature of the resulting surface. In other parts of India the sand blown from river

[1] The amount is only known at a few localities. The average rainfall at Karáchi is 7·03 inches; Umarkot, 11·8; Mooltan, 6·21; Sirsa, about the same. The rainfall at Jesalmir and Jodhpúr is unknown. At Deesa it is much greater, 34·57 inches; but the quantity increases rapidly to the eastward.

[2] For a full discussion of this subject, see the paper already quoted on the Indian desert, J. A. S. B., 1876, Vol. XLV, pt. 2, p. 97.

channels or the sea-coast is either driven by the wind into other river channels, or it is swept into them again by rain. There are sand-hills in abundance in the alluvial plain of the Indus, but they attain no great size, because the sand is always swept sooner or later into some stream, by which it is carried away towards the sea. As, owing to the increased rainfall, streams appear in Rajpútána, or to the northward, in the Ganges valley, the sand-hills disappear.

Other desert tracts.—Besides the occasional sand-hills of the Indus valley in Sind, there are some much larger tracts in the Panjáb, repeating, on a smaller scale, the phenomena of the Thar and the Rajpútána desert. The most important of these is in the Sind Ságar Doab between the Indus and Jhelum, but there is a barren tract in the Rachna Doab between the Chenáb and Rávi, and sand-hills occur in places also in the Bári Doab between the Rávi and Sutlej.

Sand denudation and striæ on rocks.—In connexion with the sand drift, the marks produced by the combined action of the wind and sand on rocks may be noticed. These are very conspicuous in places on the jurassic limestones of Jesalmir, and on the nummulitic limestones of Sind. The surface of the limestone on the plateaus close to Jesalmir is everywhere scored with grooves and striæ, striking about N. 35° E., the direction of the strong sand-transporting winds of the hot season. The resemblance to glacial markings is very great, but there is an absence of the polished surface, characteristic of ice action.

Pot-holes in river-beds.—It would be unnecessary to mention this common form of erosion but for the circumstance that it has been [1] supposed that no instances have been noticed in India, and it has hence been inferred that the phenomena are rare. On the contrary, as might be expected, pot-holes, or giants' cauldrons, are not only excessively common in the beds of Indian rivers, but, owing to the alternation of wet and dry seasons, and the consequent exposure of the river-beds to floods at one period of the year, whilst the channels remain nearly dry at other seasons, there are in India unusual facilities for studying the effects, upon rocks, of water in violent motion. Pot-holes consequently abound in the beds of all streams and rivers traversing sandstone, limestone, or any other rock of fairly homogeneous composition, including basalt and other varieties of trap, many forms of metamorphic rocks, and even quartzite. The abundance of these marks of erosion, indeed, caused them to be noticed in Southern India many years since: several were described by Benza [2] and Newbold,[3] and shewn to have been produced

[1] Proc. A. S. B., 1877, p. 79.

[2] Madras Jour. Lit. Sci. (1836); IV, p. 291, and fig. 5, p. 245.

[3] Proc. Geol. Soc., III, p. 702 (1842); Jour. Roy. As. Soc., VIII, p. 261 (1846).

by the action of water. It is almost impossible to walk for any distance along the bed of a stream traversing rock in any part of India without seeing pot-holes in abundance.[1] Very commonly, these natural basins are employed to wash clothes in, and they may be found occasionally used for steeping plants, or portions of plants, in water, for various purposes.[2]

Pre-historic human implements: Stone.—It is, of course, beyond the scope of the present work to enter into the subject of Indian archæology, or even to deal with the works of pre-historic man, such as stone circles, cromlechs, and mounds, so widely scattered over the surface of the country.[3] The discoveries of chipped implements of quartzite

[1] The following are a few instances in which the occurrence of pot-holes has been noticed by the Geological Survey:—King and Foote, near Trichinopoly, Mem. G. S. I., IV., p. (259); Hughes, in the Bokaro coal-field, Damúda valley, *ib.*, VI, p. (91); Ball, in the Rajgarh and Hingir coal-field, Máhánadi valley, Rec. G.S. I., VIII, p. 114; Foote, on the Ghatprabha and Malprabha rivers, Mem. G. S. I., XII, pp. 88, 99.

[2] Ball: Proc. A. S. B., 1877, p. 143.

[3] For information on the subject of cromlechs, cairns, menhirs, dolmens, and stone circles in India, Fergusson's "Rude Stone Monuments," pp. 455-509, may be consulted; also Lubbock's "Pre-historic Times," 3rd ed., p. 127; and the following papers relating to stone monuments in particular districts:—

Yusafzai (Eusufzye),—Proc. A. S. B., 1870, p. 5.

Khási Hills,—Hooker's Himalayan Journals, II, p. 320; Godwin-Austen, Jour. Anthrop. Inst., I, p. 122, Pls. III-VI; vol. V, p. 37, Pl. II, III.

Nágá Hills,—Godwin-Austen, Jour. Anthrop. Inst., IV, p. 144, Pls. XI-XII.

Chutia Nágpúr,—Dalton, J. A. S. B., 1873, XLII, Pt. I, p. 112, Pl. I, II.

N. B.—The stone monuments in the Khási and Nágá Hills and in Chutia Nágpúr are of modern date.

Nágpúr,—Rivett-Carnac, Proc. A. S. B., 1870, p. 55.

Wardha,—Carey, Proc. A. S. B., 1871, p. 238.

Nizam's Dominions; Eastern, near Godávári,—Mulheran, Proc. A. S. B., 1868, p. 116, Pl. I; ib., p. 148; King, J. A S. B., 1877, XLVI, Pt. 1, p. 179, Pls. XI-XII.

Nizam's Dominions; Western, near Bhima and Krishna rivers,—Jour. Bombay Br. R. A. S., III, Pt. 2, p. 179, 3 plates; vol. IV., p. 380, Pls. XIII-XVII; Trans. Roy. Irish Acad., XXIV, Antiquities, pp. 329—363. These accounts by the late Captain Meadows Taylor are particularly interesting.

Maisur (Mysore),—Cole, Indian Antiquary, II, p. 86.

Kurg (Coorg),—Cole, Proc. A. S. B., 1868, p. 151, Pl. II; ib., pp. 184, 243; 1869, pp. 54, 202, 226.

Nilgiris,—Congreve, Madras Jour. Lit. Sci., XIV, 1847, p. 77; Saxton, Proc. A. S. B., 1870, p. 52.

Malabar,—Babington, Trans. Lit. Soc. Bombay, III, p. 324, Pl. A. D. E. (1820).

Guntur,—Fergusson, J. R. A. S., new Series, III, p. 143.

Coimbatur,—Walhouse, J. R. A. S., new Series, VII, p. 17.

Salem,—Phillips, Indian Antiquary, II, p. 223.

Carnatic,—Congreve, Mad. Jour. Lit. Sci., XIII, p. 47 (1844).

Tinnevelly,—Kearns, Mad. Jour. Lit. Sci., XXI, p. 27.

The above is not a complete list of references, but it will probably suffice to aid any one interested in the subject. Some additional references will be found in Fergusson's "Rude Stone Monuments."

in the low-level laterite of Madras, of a similarly chipped axe or scraper in the alluvial deposits of the Narbada (Pl. XXI, fig. 1), and of a flake, apparently of human munufacture, in the Godávari gravels (fig. 2), have already been noticed. These are the only well-ascertained cases in which implements have been found in clearly-defined formations, but similar objects of human manufacture occur abundantly, either scattered over the surface, or in the superficial gravels, or even in river deposits.

Palæolithic.—The oldest kinds of human implements found in India consist of chipped stones of peculiar shape, sometimes known as "spear heads," "axes," and "scrapers," the commonest shapes being either flattened in one direction and ovate in the other, (the scrapers,) or less flattened and pear-shaped, (the spear heads). The axe-head forms, with a straight-cutting edge at one end, and either rounded or attenuate at the other extremity, are rarer. The common types are similar to those of the well-known flint implements found in Europe, and especially near Abbeville in France, and very much like those figured at pages 114 and 115 in Lyell's "Antiquity of Man," but the material in India is not flint, but quartzite. Implements of vein quartz and of greenstone have also been found.

Chipped implements of the Abbeville type were first found in large numbers near Madras [1] by Messrs. Foote, King, and C. Oldham, and subsequently to the northward as far as the Godávari. A few have also been found in South-Eastern Bengal, Orissa, in various parts of the Central Provinces, and in Assam.[3] The material has, in almost all cases, been derived from the quartzites of the Vindhyan or transition series, either directly, or else from pebbles of the quartzites occurring in later formations.

Flakes or stone knives and cores.—The flakes or stone knives made from agate, flint, or chert, are doubtless in part of equal antiquity with the quartzite implements, but it is at least possible that many are of more recent origin, and it is certain that precisely similar flakes are still used by the Andaman Islanders, although, since the advent of Europeans to the islands the inhabitants have preferred glass bottles to chert as a material for the manufacture of cutting implements. Flakes made of agate are found commonly throughout the area of the Deccan trap in which agates abound; the chips are usually of very small size, from one to two inches in length, and polygonal cores, either prismatic or

[1] Foote: Madras Jour. Lit. Sci., Ser. 3, Pt. 2, p. 1., Pls. I-XV (1866); Q. J. G. S., 1868, p. 484; Mem. G. S. I., X, p. 43; numerous figures accompany the paper first quoted.

[2] P. A. S. B., 1871, p. 179.

[3] For a list of references to notices up to date, of the occurrence of stone implements, see Ball, Proc. A. S. B., 1867, p. 148; also Proc. A. S. B., 1876, p. 122.

conical, from which flakes have been split, are met with in considerable numbers, especially on the edge of the trap area. They were first noticed near Jabalpur by Lieutenant Swiney,[1] and have since been found at Nágpúr and elsewhere.

In Sind, on the hills near Sukkur and Rohri, immense quantities of imperfect flakes and cores are found made from the flint, which abounds in the nummulitic limestone. Many of the cores are 3 to 4 inches long. Some smaller but very perfectly and regularly shaped cores of the same material have also been found in the bed of the Indus at Sukkur[2]: one of these is figured on Plate XXI, fig. 3.

Neolithic.—The later or neolithic forms of stone implements, known as "Celts," in which the surface has been smoothed by grinding, are also found in India. They were first noticed by Mr. H. P. LeMesurier[3] in Bundelkhand, especially around Kirwi, and in the adjoining district of Bánda, where they appear to exist in considerable numbers. The material of which they are composed is usually a kind of greenstone, but some are of as chistose rock. One specimen is also recorded from Behár[4] three from Chutia Nágpúr and Hazáribágh,[5] one from Kúrg (Coorg,[6]) and several, some of which are of jade, from Assam[7]; some have also been found in the Andaman Islands.[8] All hitherto noticed closely resemble forms common in Europe, and one of the most characteristic is represented in Pl. XXI, fig. 4. A totally different type of neolithic weapons is common in Burma,[9] but has hitherto only been found, in India, in Chutia Nágpúr.[10] This form is distinguished by having more or less the form of an axe or adze, one end being cut away at both sides into shoulders, so as to leave re-entering angles into which a handle could be fitted, (Pl. XXI, fig. 5.) The Chutia Nágpúr implements are of quartzite or of some igneous rock; the Burmese are usually of hard sandstone, slate, schist, or limestone. Perforated ring stones or spindle whorls[11] and hammer heads have also been found in various parts of the country.

[1] Proc. A. S. B., 1865, p. 77; 1866, p. 230, Pls. III, IV; 1867, p. 136; 1869, p. 51.

[2] Evans, Geol. Mag., 1866, p. 433, Pl. XVI; P. A. S. B., 1875, p. 134.

[3] J. A. S. B., 1861, XXX, p. 81; see also Theobald, J. A. S. B., 1862, XXXI, p. 323. Several kinds are figured on two plates accompanying the latter paper.

[4] Theobald, l.c.

[5] Ball, Proc. A. S. B., 1870, p. 268; 1878, p. 125.

[6] H. A. Mangles, P. A. S. B., 1868, p. 59.

[7] Lieut. Steel, P. A. S. B., 1870, p. 267, Pls. III, IV; S. E. Peal, *ib.*, 1872, p. 136.

[8] Stoliczka, P A. S. B., 1870, p. 17.

[9] Theobald, P. A. S. B., 1865, p. 126; 1869, p. 181, Pls. III, IV; 1870, p. 220: Mem. G. S. I., X, p. (355), Pls. III, IV, V, VI, VIII, IX.

[10] Ball, P. A. S. B., 1875, p. 118, Pl. II.

[11] P. A. S. B., 1866, p. 135, Pl. I; 1874, p. 96, Pl. V; 1875, p. 102: Mem. G. S. I., X, p. (358), Pl. VII.

Copper, silver, and bronze implements.—In Europe the earliest metallic weapons found associated with the remains of man are usually made of bronze, but as bronze is an alloy of copper and tin, and as the latter metal is never found native, and requires some metallurgical skill for extraction from the ore, it has been inferred that a knowledge of the use of copper, which not unfrequently is found in the native state, must have preceded the manufacture of bronze, although pure copper implements are, in Europe, of extremely rare occurrence. In North America, however, where native copper occurs locally in great abundance, implements made from the pure metal are more common. Hitherto but few copper weapons have been noticed in India, but still they have been found more frequently than bronze. Of the latter metal, indeed, but a solitary example appears hitherto to have been discovered: an axe was found[1] in the neighbourhood of Jabalpur, but no details of the discovery have been recorded. An analysis by Mr. Tween shewed that the composition was: copper 86·7, tin 13·3, per cent.

Two copper axes, a copper spear head, and some bracelets of the same metal, were found in a field near Mainpuri in the North-West Provinces.[2] One of the axes closely resembles a flat form of celt common in Europe; the spear head is cut at the edge into a series of pointed teeth; the bracelets are identical in form with the "ring-money" of antiquarians. Another important discovery of 404 copper implements and 102 pieces of silver was made near the village of Gangeria in Bálaghát district, Central Provinces.[3] The copper is in the form of axes and of long chisel-shaped implements, broader at the end; the silver in peculiar thin forms, probably intended for ornament. All were found buried together in a spot until recently covered by forest. A discovery of very rude pieces of copper was made near Pachumba in the Hazáribágh district,[4] and a fine copper axe or celt, 8 inches long, 2½ broad, and about ½ inch thick in the middle, was lately found at Bhagotoro near Sehwán, in Sind, in excavating for the Indus State Railway. In no known case have bronze or copper implements been found in India in connexion with other works of man, except in some instances in which articles made of iron were associated.

Iron implements.—Weapons and other objects made of iron are found abundantly in many parts of India in stone circles, or associated with cromlechs and other stone monuments, many of which appear to be of great antiquity, and to have been erected by tribes long since extirpated or driven from the country. The erection of rude stone monoliths is

[1] R. Strachey, Proc. A. S. B., 1869, p. 60.
[2] Proc. A. S. B., 1868, pp. 251, 262.
[3] Proc. A. S. B., 1870, p. 131, Pl. II.
[4] Proc. A. S. B., 1871, p. 231.

still practised by some of the wilder tribes of India,[1] so that the date of such erections is in many cases doubtful. There can be little, if any question, however, that many of the stone circles of the Central Provinces and the "Korumba rings" of Southern India date from a period previous to the Arian immigration, and they were possibly contemporaneous with the very similar remains found in Europe and Central Asia. In Europe, however, stone circles and cromlechs are considered characteristic of the bronze age; whereas in India, iron implements have been found associated with them in several places, amongst others near Nágpúr,[2] in the Wardha district,[3] near Ferozabad,[4] and Sorapur,[5] east of Hyderabad in the Deccan, in Maisur[6] (Mysore) and Kúrg[7] (Coorg), on the Nilgiri hills,[8] in Malabar,[9] Coimbatur,[10] Salem,[11] and Tinnevelly.[12] It appears not improbable that iron may have been manufactured in India at an earlier period than in Europe, and that the paucity of bronze weapons discovered in India and the comparative abundance of iron are due to the short period which elapsed, in Southern Asia, between the first discovery of the art of metallurgy and the invention of a process for extracting iron from its ores. At the same time there can be no question that the comparatively mumerous discoveries of iron implements are due to the association of those implements with conspicuous stone monuments, and the apparently rare occurrence of copper and bronze weapons may be caused by the want of any similar marks to indicate the position in which human works of the earlier metallic ages lie buried. It is only within the last few years that attention has been fully attracted to the subject of human pre-historic remains, and it may fairly be hoped that much remains to be ascertained. In all probability, there are few countries in the world where more important results may be anticipated than in India; every probability appears to point to the tropics as the original habitat of the human race; there is no other tropical country with so long an authentic history as India, and but few in which pre-historic remains are known to be so abundant.

[1] See foot-note to p. 440.

[2] Rivett-Carnac: Proc. A. S. B., 1870, p. 54.

[3] Carey: Proc. A. S. B., 1871, p. 238; some articles of copper were also found.

[4] Meadows Taylor: Jour. Bombay Br. R. A. S., III, Pt. 2, p. 179, Pl. VI.

[5] Meadows Taylor: Jour. Bombay Br. R. A. S., IV, p. 380.

[6] Cole: Indian Antiquary, II, p. 86.

[7] Cole: Proc. A. S. B., 1868, p. 186, Pl III.

[8] Saxton: Proc. A. S. B., 1870, p. 52; Walhouse, Indian Antiquary, II, p. 276.

[9] Babington: Trans. Bombay Lit. Soc., III, p. 324, Pl. C.

[10] Walhouse: J. R. A. S., new ser., VII, p. 17.

[11] Phillips: Indian Antiquary, II, p. 225.

[12] Kearns: Mad. Jour. Lit. Sci., XXI, p. 27.

A MANUAL

OF

THE GEOLOGY OF INDIA.

PART II: EXTRA-PENINSULAR AREA.

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Sub-division of the extra-peninsular area.—The distinctions in geological characters between the peninsular and extra-peninsular areas of India have already been explained, and the reasons for treating the two regions separately have been sufficiently stated in the introductory chapter; whilst the descriptions of the tertiary, and still more of the post-tertiary, formations of the Peninsula furnish a natural passage to the extra-peninsular area. This is geologically an intrinsic portion of the Asiatic continent, whilst peninsular India is not.

Imperfect as is our knowledge of the geology of the Indian Peninsula, our acquaintance with the geological structure of the mountain ranges west of the Indus, of the Himalayas, and of the countries east and north-east of the Bay of Bengal, is even more fragmentary. Occasionally wide areas intervene, such as Nepal and the outer hills of the Afghan highlands, from which Europeans are rigidly excluded, and, even when no political difficulties exist, the physical impediments to surveying are of the most serious description. Many parts of the mountainous barrier which almost surrounds India are, from their great elevation and rigorous climate, only habitable for a short period of the year, and even then their exploration is a matter of difficulty; population is sparse, and roads either difficult or wanting throughout the whole tract. To the eastward, in the damper regions of Assam, Sylhet, and Burma, the denseness of the forest throughout nearly the whole of the country, and the impenetrable undergrowth of creepers, canes, bamboos, and shrubs, render the examination of the rocks toilsome, tedious, and unsatisfactory. To crown the whole, throughout extra-peninsular India, with the exception of Sind and the Panjáb, the geology is greatly obscured by the disturbance and, in many parts, the metamorphism which the rocks have undergone.

Owing to these various drawbacks, it is not practicable to treat the geology of extra-peninsular India as has been done in the case of the peninsular area, and to describe each formation throughout the whole region by itself. Having to deal with fragmentary and isolated observations, varying greatly in their amount of detail, it appears best to take each geological tract separately; and this arrangement is facilitated by the fact that there is a wide distinction between different parts of the region, both in the formations represented, and in the physical features of the geology, such as the directions of the mountain chains. The plan that will be adopted in describing the extra-peninsular tracts will be to commence at the west with Sind, as the rocks of that province are not only closely connected with the tertiary formations of Cutch and Kattywar, described in the fourteenth chapter, but are also of importance as affording a better series of the tertiary beds, so widely developed in extra-peninsular India, than is known elsewhere in Southern or South-Eastern Asia.

The following regions will therefore be separately described:—

I. Sind.
II. Panjáb hills west of the Jhelum.
III. Himalayas.
IV. Assam, Sylhet, Chittagong, &c.
V. Burma.

I. Sind:—**Physical geography of Western Sind.**—The greater part of the province of Sind is included in the Indo-Gangetic plain, already described in Chapter XVII; Eastern Sind, beyond the limits of the Indus alluvium, consists chiefly of sand-hills, and the rock area of the province is almost limited to the ranges of hills on the western or Baluchistán frontier, and a few isolated ridges in the alluvium; the most important exposures amongst the latter being those near Sukkur (Sakhar) and Rohri (Roree).

The province is commonly divided into Upper and Lower Sind, the former lying north, the latter south of Sehwan. Upper Sind consists of a broad alluvial plain on both sides of the river, interrupted near Sukkur and Rohri by the ridges of limestone already mentioned, and bounded to the westward by a north and south mountain chain, known as the Khirthar,[1] forming the boundary between Sind and Baluchistán, and rising in places to 6,000, and even in one spot to 7,000, feet above the sea. Lower Sind, west of the Indus, consists of a series of parallel north and south ridges of no great height, seldom exceeding 2,000 feet above the sea, but much loftier to the north than to the south, where they almost disappear in an undulating plain near the coast. Many of

[1] This range in all the older maps is united with other hills on the western border of Sind, and the whole is called the Hála range. No such range is recognised in the country. There is a Hála pass, not in the Khirthar range, but in another much smaller ridge south of Sehwan.

these ridges are simple anticlinals, the axes being formed of the massive nummulitic limestone of which the highest portion of the Khirthar also consists. The Khirthar range terminates in Lower Sind some distance south of Sehwan; other ridges, however, both east and west of this main range, extend farther to the south. East of the Indus there is an isolated low range of limestone hills, on the northern extremity of which stands the town of Hyderábád, and there is another similar rise at Tatta.

The hills of Baluchistán, west of Sind, are very imperfectly known; for some distance from the Sind frontier they form ranges running north and south parallel to the Khirthar, but farther west they assume an east and west direction. They are principally composed of tertiary rocks, like the hills of Sind, but at Kelat itself, and in a few other localities, older formations have been discovered,[1] and some apparently extensive igneous rocks also occur.

Rock formations.—The rocks found in Sind,[2] as already noticed, belong chiefly to the tertiary epoch, but in one locality some cretaceous beds crop out from beneath the higher formations. The following is a list of the different groups, exclusive of the alluvium:—

Name.	Sub-divisions.	Approximate thickness.	Supposed geological age.	Remarks.
1. MANCHHAR	upper	5,000	*pliocene.*	Apparently representative of the Siwaliks proper.
	lower	3,000 to 5,000	*lower pliocene or upper miocene.*	
2. GAJ	......	1,000 to 1,500	*miocene.*	
3. NARI	upper	4,000 to 6,000	*lower miocene?*	
	lower	100 to 1,500	*upper eocene.*	
4. KHIRTHAR	upper	500 to 3,000	*eocene.*	Nummulitic limestone.
	lower	6,000?	*eocene.*	The base not determined.
5. RANIKOT	......	2,000	*lower eocene.*	
6. TRAPS	......	40 to 90	*upper cretaceous.*	Representative of Deccan and Malwa trap.
7. CRETACEOUS	*a. Cardita Beaumonti* beds	350 to 450	*cretaceous.*	
	b. Sandstones	700		
	c. Hippuritic limestone	320		Base not exposed.

[1] Cook, Trans. Med. Phys. Soc. Bombay, 1860, VI, pp. 1,45; Carter, Jour. Bombay Br. R. A. S., VI, p. 184. It is possible that some of the igneous rocks described as occurring may be interstratified and representative of the Deccan trap, as in Sind.

[2] This description is taken partly from the accounts of Sind geology given in Rec. G. S. I., IX, pp. 8—22, XI, pp. 161—173, and partly from manuscript notes. Some details were given previously, Mem. G. S. I., VI, pp. 1—12. The earliest description of the geology of Sind was by Vicary, Q. J. G. S., 1847, p 334. The fossils obtained by Vicary and others were described in Messrs. D'Archiac and Haime's great work, the "Description des animaux fossiles du groupe Nummulitique de l'Inde," published in 1853.

Of these rocks, the lower Khirthars and the Ranikot beds may be, to some extent, representative of each other. On the river Gáj, which traverses the Khirthar range in Upper Sind, a thickness of at least 25,000 feet of strata is exposed, none of the fossiliferous beds being of older date than eocene; but some of the rocks towards the base of the section beyond the Sind frontier correspond so well with the description given by Dr. Cook of strata in which he found mesozoic fossils (*Ammonites*, &c.) in Kelat, that these bottom beds on the upper Gáj, which are only seen west of the British frontier, may very probably be of cretaceous age. There is, however, no resemblance between any of the lower beds on the Gáj and the cretaceous rocks of the Laki range.

Cretaceous beds.—The only locality in Sind, in which beds of older date than eocene have been identified, is in a range of hills running due south from the neighbourhood of Sehwan, and generally known to Europeans as the Laki range,[1] from the small town of Laki near the northern extremity. South-west of Amri on the Indus, a number of very dark-coloured hills are seen in this range; they contrast strongly with the cliffs of grey and whitish nummulitic limestones behind them. These dark hills consist of cretaceous beds, but the lowest member of the series is only exposed in a single spot, at the base of a hill known as Bárrah, lying about 10 miles south-west of Amri. The whole range here consists of three parallel ridges, the outer and inner composed of tertiary rocks; while the intermediate one consists of cretaceous beds, faulted to the eastward against the lower eocene strata and dipping under them to the westward. Close to the fault some whitish limestone is found, compact and hard; the lower portion pure; the upper portion, often containing ferruginous concretions, is sandy, gritty, and forms a passage into the overlying sandstones. The base of this limestone is not seen; the whole thickness exposed is a little over 300 feet, and the length of the outcrop does not exceed half a mile. The limestone is fossiliferous, and contains echinoderms and mollusca, but it is so hard and homogeneous that nothing that has been obtained from it can be easily recognised, except one fragment of a hippurite. This fossil is, however, of great importance, because it shews that the white limestone may very probably be an eastern representative of the hippuritic limestone, so extensively developed in Persia, and found in numerous localities[2] from Tehrán to east of

[1] This range has no general name, different portions being known by a number of local terms. It is one of the ranges which combines to form the Hála range of Vicary and other writers, and the name is less inappropriate in this case, for there is an unimportant pass through the chain known as the Hála Lak. Different portions of the range are known as Tiyún, Kára, Eri, Surjána, &c. The range is very incorrectly represented on the maps.

[2] Eastern Persia, II, pp. 457, 485.

Karmán in longitude 58°, just ten degrees west of the Laki range in Sind. Of course the same formation may be found in the intervening country, the geology of which is unknown. The precise position of the Persian hippuritic limestone in the cretaceous series has not been determined, but the European formation, which is very similar and probably identical, is of the age of the lower chalk (turonian).

The sandstones resting on the hippuritic limestone occupy a considerable tract around Bárrah hill, and extend for about 3 miles from north to south. They are also seen at Jakhmari to the northward, and in one or two other places in the neighbourhood. They are gritty and conglomeratic, frequently calcareous, and contain a few bands of shale, usually of a red colour. The prevailing colour on the weathered surfaces is dark brown or purple, many of the beds being highly ferruginous. On the top of the sandstones is a thick bed of dark-coloured impure limestone, containing oyster shells, and occasionally large bones, apparently of reptiles; none, however, have been found sufficiently well preserved for identification.

In one place a bed of basalt, about 40 feet thick, has been found interstratified in the sandstones, and it is possible that the band may exist elsewhere, but it has hitherto remained undetected. The position of this bed of basalt on the face of a hill called Bor, about 13 miles north of Ranikot, is at an elevation of 300 or 400 feet above the base of the sandstones, and about twice as much beneath the main band of interbedded trap, to be described presently.

The highest sub-division of the cretaceous formation consists of soft olive shales and sandstones, usually of fine texture. The sandstone beds are thin, and frequently have the appearance of containing grains of decomposed basalt or some similar volcanic rock, or else fine volcanic ash. A few hard bands occur, and occasionally, but rarely, thin layers of dark olive or drab impure limestone. Gypsum is of common occurrence in the shales.

Palæontology.—The olive shales are highly fossiliferous, the commonest fossil being *Cardita beaumonti*,[1] a peculiar, very globose species, truncated posteriorly, and most nearly allied to forms found in the lower and middle cretaceous beds of Europe (neocomian and gault). This shell is extremely abundant in one bed, about 200 to 250 feet below the top of the cretaceous series, but is not confined to this horizon. *Nautili* also occur, the commonest species closely resembling *N. labechei*[2] of Messrs. D'Archiac and Haime, but differing in the position of the siphuncle. This form appears undistinguishable from *N. bouchardianus*, found in the upper cretaceous Arialur beds of Pondicherry, and at a lower

[1] D'Archiac and Haime, An. foss. Groupe Num., p. 253, pl. xxi, fig. 14.
[2] T. c. p. 338, pl. xxxiv, fig. 12.

cretaceous horizon in Europe. A second *Nautilus* resembles *N. subfleuriausianus*, another eocene Sind species, in form, and is also allied to some cretaceous types. Several *Gasteropoda* occur, especially forms of *Rostellaria, Cypræa, Natica* and *Turritella,* but none are very characteristic. Two forms of *Ostrea* are common—one of them allied to the tertiary *O. flemingi* and to the cretaceous *O. zitteliana,* but distinct from both. The only mollusk which certainly passes into the Ranikot beds is *Corbula harpa*. Two echinoderms have been found—one is an *Epiaster,* an almost exclusively cretaceous genus, only one or two tertiary species having been found; the other is an aberrant form of *Echinolampas*. Two or three corals complete the list of invertebrate fossils found in the olive shales.

In the lower part of the beds with *Cardita beaumonti,* however, some amphicœlian vertebræ were found, which Mr. Lydekker has ascertained to be crocodilian. All amphicœlian crocodiles are mesozoic, and the present form must be one of the latest known. So far as it is possible to form an opinion from very fragmentary materials, the vertebræ in question appears more nearly allied to the Wealden *Suchosaurus* than to any other form hitherto described. It has, however, been already shewn, when writing of the Gondwána flora, that the distribution of *Reptilia* in past ages was not the same in India as in Europe.

The fossils of the *Cardita beaumonti* zone require much fuller examination and comparison than they have hitherto received, but sufficient has been ascertained to shew that they have a distinctly cretaceous character, and that the limit of tertiary formations must be drawn above them. As will be seen in the description of the Panjáb Salt Range in the next chapter, it is probable that this peculiar band of olive-coloured shales is represented by similar beds in that locality also. It has, however, not hitherto been recognised in Baluchistán or in the Western Panjáb, south of the Salt Range.

Deccan trap.—Mention has already been made of one bed of basalt intercalated in the sandstones above the hippuritic limestone: a much more important band of the same igneous rock has been traced, resting upon the *Cardita beaumonti* beds, throughout a distance of 22 miles from Ranikot to Jakhmari, about 17 miles south of Sehwan, wherever the base of the Ranikot group, the lowest tertiary formation, is exposed. The thickness of this band of trap is trifling, and varies from about 40 to about 90 feet. Apparently in some places the whole band consists of two lava flows similar in mineral character, except that the upper is somewhat ashy, and contains scoriaceous fragments; the higher portion of each flow is amygdaloidal, and contains nodules of quartz, calcedony and calcite, and in places the nodules are surrounded by green earth, as is

so frequently the case in the Deccan traps. Another characteristic accessory mineral, common also in the traps of the Deccan and Malwa, is quartz with trihedral terminations. The basaltic trap of the Laki hills is apparently of subaërial origin, although it rests conformably on the marine (or estuarine?) *Cardita beaumonti* beds. There is nothing in the igneous bed to indicate its having consolidated otherwise than in the air, and the structure differs altogether from that of subaqueous volcanic tuffs.

The evidence that this band of basaltic rock is interstratified and not intrusive is ample; throughout the whole distance the trap is found in precisely the same position between the lowest beds of the Ranikot group and the highest cretaceous strata, and apparently perfectly conformable to both. The close resemblance in mineral character and the similarity of geological position at the base of the tertiary beds shew that this band must be in all probability a thin representative of the great Deccan and Malwa trap formation, and the occurrence of a second bed at a lower horizon, interstratified with rocks of cretaceous age, tends strongly to confirm the inference drawn from the relations of the traps to cretaceous and tertiary rocks in the Narbada valley, that the great volcanic formation of Western India must be classed as upper cretaceous.

Ranikot group.—The name of the lowest tertiary sub-division is derived from a hill fortress of the Sind Amirs, situated in the Laki range of hills, and known as Rani-jo-kot, or Ranikot, and also as Mohan-kot, from the Mohan stream, which traverses the fortification. The Ranikot group is much more extensively developed in Sind than the underlying cretaceous beds, for although it is confined to Lower Sind, and although its base is only seen in the Laki range, north of Ranikot, its upper strata occupy a considerable tract of country, about 26 miles long from north to south by about 12 in breadth, north-west of Kotri, and another even larger exposure, about 36 miles long, occurs, extending from north of Jhirak (Jhirk, Jhirruk, Jerruck or Jurruk) to Tatta. In the Laki range, the Ranikot beds are seen for about 35 miles, but the outcrop is never more than 2 or 3 miles broad, and one small inlier is exposed to the west of Ranikot.

All the lower portion of the Ranikot group, including by far the greater portion of the beds, consists of soft sandstones, shales and clays, often richly coloured and variegated with brown and red tints. Gypsum is of frequent occurrence; some of the shales are highly carbonaceous; and in one instance a bed of coal (or lignite) nearly 6 feet thick was found, and a considerable quantity of the mineral extracted.[1] The quality was, however, poor, and from the quantity of iron-pyrites present, the coal decomposed rapidly, and was liable to spontaneous combustion

[1] Mem. G. S. I., VI., p. 13.

when exposed, whilst the deposit was found to be a small patch, not extending more than about 100 yards in any direction. Some of the more pyritous shale is used in the manufacture of alum. The only fossils found in the lower portion of the Ranikot group, with the exception of a few fragments of bone, have been plants, some dicotyledonous leaves, hitherto not identified, being the most important. All the Ranikot beds, except towards the top of the group, have the appearance of being of fresh-water origin, and are probably fluviatile.

A variable portion of the group, however, towards the top, consists of highly fossiliferous limestones, often light or dark brown in colour, interstratified with sandstones, shales, clays, and ferruginous bands. These are the lowest beds in Sind containing a distinctly tertiary marine fauna. The brown limestones are well developed around Lynyan, east of Band Vero and north-west of Kotri, and throughout the area of Ranikot beds near Jhirak and Tatta. In this part of the country there appears to be a complete passage upwards into the overlying nummulitic limestone (Khirthar); but in the Laki range, the upper marine beds of the Ranikot group are poorly represented or wanting, and it is evident that they were removed by denudation before the deposition of the Khirthar limestone, for the latter is seen at Hothian Pass resting upon their denuded edges.

The greatest thickness of the Ranikot group in the Laki range, where alone, as has already been explained, the base of the group is visible, is about 2,000 feet, but generally the amount is rather less, about 1,500. It must, however, be recollected that in this locality some of the upper marine beds are wanting, and as these marine limestones and their intercalated shales, sandstones, &c., are 700 or 800 feet thick, in places northwest of Kotri, it is evident that the original development of the group exceeded the 2,000 feet seen in the Laki range.

Palæontology.—The following are some of the commonest or most important fossils of the Ranikot group. The large collections made by the Geological Survey have as yet only been partially examined, and the lists of fossils given can be considered only preliminary,[1] many of the commonest species being undescribed forms :—

CEPHALOPODA.

Nautilus subfleuriausianus. *N. forbesi.*
N. deluci.

[1] As in other lists in this chapter, most of the names are taken from D'Archiac and Haime's "Animaux fossiles du groupe nummulitique de l'Inde." In this work, however, species from upper cretaceous, eocene and miocene beds are described; until the rocks of Sind were surveyed, the distribution of the fossils was not known, although indications of a probable sub-division had been pointed out by D'Archiac and Haime, (t. c. p. 359), and it had been shewn by Jenkins (Q. J. G. S., 1864, p. 65), and by Martin Duncan (ib., p. 66, and Ann. Mag. Nat. Hist. Ser. 3, Vol. XIII, p. 295), that some of the fossils described indicated the presence of miocene beds.

GASTEROPODA.

Rostellaria angistoma.	*Voluta jugosa.*
R. prestwichi.	*Natica longispira.*
R. fusoides.	*Nerita (Velates) schmedeliana.*
Terebellum distortum.	*Turritella angulata*, var.
T. plicatum.	*T. assimilis.*

LAMELLIBRANCHIATA.

Corbula harpa.	*Ostrea flemingi.*
Vulsella legumen.	*O. vesicularis.*
Spondylus roualti.	

BRACHIOPODA.

Terebratula, cf. *subrotunda.*

ECHINODERMATA.

Schizaster, sp.	*Echinolampas*, cf. *subsimilis.*
Hemiaster digonus.	*Temnopleurus valenciennesi.*
Eurhodia morrisi.	*Salenia*, 2 sp.
Prenaster, sp.	*Phymosoma*, sp.
Toxobrissus, sp.	*Porocidaris*, sp. (spines).
Conoclypeus, sp.	*Cidaris halaensis.*

ANTHOZOA.

Trochocyathus vandenheckei.	*Montlivaltia jacquemonti.*
Cyclolites vicaryi.	

FORAMINIFERA.

Operculina canalifera.	*Nummulites irregularis.*
Nummulites spira.	*N. leymeriei.*

In the above list the majority of forms, such as the *Foraminifera*, the majority of the *Echinodermata* and *Gasteropoda* are lower tertiary, but still there is a very distinct admixture of species with cretaceous affinities, such as the *Nautili*, all of which are connected rather with cretaceous than with tertiary types, the *Terebratula*, which cannot be distinguished from one of the commonest upper mesozoic species, and forms of *Salenia*, *Cyclolites*, &c. *Corbula harpa* is the only form hitherto recognised that is also found in the upper cretaceous olive shales, but a variety of the same shell is also found in the Nari beds.

Cretaceous and lower tertiary rocks of Baluchistan.—All the rocks described in the last few pages as occurring below the nummulitic limestone or Khirthar group are found in Lower Sind, and, so far as is known, are confined to a tract near the right bank of the river Indus. Farther to the westward the series of older tertiary and upper cretaceous rocks has not been thoroughly examined, but the information hitherto obtained appears to shew that the strata below the nummulitic limestone are very different in character from those found in Lower Sind. In

Baluchistán, west of the frontier of Upper Sind, lower beds crop out from beneath the massive nummulitic (Khirthar) limestone, forming the crest of the intervening range of hills, and on the banks of the Gáj river which traverses the range south-west of Mehar, a series of more than 10,000 feet of strata is exposed below the Khirthar group. The following is a rough section of the rocks thus exposed, the thickness being merely an approximation :—

		Feet.
KHIRTHAR	1. Massive nummulitic limestone, forming the crest of the Khirthar range	1,200
	2. Shales, marls and clays, mostly dark-olive in colour, abounding in *Nummulites*	500
	3. Hard grey limestone, with *Nummulites*	60
	4. Argillaceous limestone, shales and clays, olive and bluish grey in colour, abounding in *Nummulites*	400
LOWER KHIRTHAR	5. Unfossiliferous olive and bluish-grey clays and nodular shales, no limestone bands	1,500
	6. Pale-brown sandstones in thick beds with vegetable markings	1,000
	7. Fine greenish-white sandstone and shale, some of which is carbonaceous	500
	8. Dark-brown limestone and dark-green argillaceous beds, with *Nummulites*	100
	9. Pale-grey argillaceous limestone, with but few fossils; one band towards the base contains *Nummulites* and *Alveolinæ*	200
? CRETACEOUS	10. Fine dark-coloured shales, unfossiliferous	3,000
	11. Very fine grained homogeneous thin-bedded limestones, white, red, grey, or ochrey in colour, unfossiliferous, forming a conspicuous range	1,200
	12. Hard grey shales with calcareous bands from an inch or two to a foot in thickness	2,500
	The base not exposed.	
		12,160

About this section the first point to be observed is that none of the beds resemble those seen in Lower Sind sufficiently to enable any of the strata of the two localities to be identified with certainty. The sandstone No. 6 may correspond to the sands and clays of the Ranikot group, but there is no great similarity, and nothing in the above section appears to represent the fossiliferous brown limestones of the Ranikot group, the Deccan trap, the olive shales with *Cardita beaumonti*, or any other of the cretaceous beds in the Laki hills. So far, indeed, as the section on the Upper Gáj river is concerned, all the rocks exposed might be referred to the tertiary epoch and classed as lower eocene; no marked break intervenes anywhere, nor are there any fossils below the argillaceous limestone with nummulites, No. 9, to shew the age of the beds. But, as has

already been noticed, farther to the westward, near Khozdár, in Baluchistán, Dr. Cook discovered *Ammonites* [1] in some argillaceous beds, passing upwards into red and white limestone, and it appears probable from the description that the latter is identical with the fine-grained thin-bedded limestone, No. 11, of the preceding section, whilst the argillaceous beds may be the same as No. 12.

The following section, abridged from that given by Dr. Cook,[2] shews the nature of the rocks between Kelat and Khozdar, the latter place lying about 70 miles north-north-west of the section on the upper Gáj river :—

		Feet.
EOCENE	1. Compact white or reddish-white limestone containing *Nummulites, Orbitolites, Orbitoides, Alveolina,* &c. (This is doubtless the Khirthar limestone.) Thickness unknown; probably more than	1,000
	2. Limestone strata, differing in character, compact, sub-crystalline, saccharoid, at times cretaceous, containing *Nummulites (Assilina), Alveolina,* and minute indistinct *Foraminifera* and passing downwards into coloured argillaceous strata	? 200—500
MESOZOIC	3. More or less compart, fine grained red and white limestone interleaved with slabs of flint or chert, the upper part containing one or two massive strata of an excessively hard limestone, abounding in *Orbitoides, Orbitolina,* and *Operculina,* the lower strata becoming argillaceous and shaly and containing (rarely) *Ammonites* .	? 2,000
	4. Dark-blue fossiliferous limestone containing strata yielding lead ore (galena and carbonate of lead) .	? 2,000
	5. Clay slate	? 2,500

It is true that the precise relations of many of these beds are far from clear. Thus, in the valley of Kelat, the red and white limestone appears to underlie strata containing *Orthoceratites.* This may, however, be due to faulting or inversion. It is probable that several different groups of beds occur near Kelat, for amongst the fossils, besides *Orthoceratites, Ammonites* of jurassic types, *Ceratites, Crioceras, Scaphites* and *Belemnites* occur, and whilst some of the forms are typically cretaceous, others can scarcely be newer than triassic.

It is not impossible that the limestone bands in No. 3, containing *Orbitoides* and other *Foraminifera,* may belong to the tertiary series and

[1] Jour. Bombay Br. R. A. S., VI, pp. 186, 188.

[2] Bombay Med. Phys. Soc. Trans, 1860, VI, p. 100. The bed numbered 2 in the section is called upper cretaceous by Dr. Cook, but with a mark of doubt. This was perhaps in accordance with the views as to the classification of the beds beneath the nummulitic limestone formerly held by Dr. Carter, but subsequently modified by him. See Jour. Bombay Br. R. A. S., IV, pp. 93, 95, V., p. 635, and "Geological papers on Western India," pp. 623, 626, 699, 700, footnote, &c.

not to the group with which they are associated. The banded fine grained white or red and white limestone is a conspicuous and important bed, and is probably widely developed in Baluchistán. It was found by Dr. Cook at several places south and south-west of Kelat; it occurs, as already shown, on the upper Gáj river west of the Khirthar range, forming a range of hills known as Parh, and a rock of precisely the same mineral character appears 130 miles further south on the coast at a small hill called Gadáni, about 25 miles north-west of Karáchi. If, as appears probable, this peculiarly fine limestone or calcareous shale (for the rock in places appears argillaceous) belong to the upper portion of the cretaceous series, it will serve to mark that horizon in Baluchistán and facilitate the recognition of the indistinct limit between mesozoic and tertiary. There is, however, a great appearance of passage between all these formations.

Returning to the beds of the Gáj section, the gradual passage upwards from the shales, marls, and clays with *Nummulites*, Nos. 2, 3, and 4 of the section, into the massive nummulitic limestone is worthy of notice. A similar passage takes place locally in Lower Sind, and it appears best to consider the shales and marls as the lower portion of the same group as the limestone. The six thousand feet of rocks remaining between the nummulitic shales and the banded limestones of supposed cretaceous age may be classed as lower Khirthar; they very possibly represent the Ranikot group, but, as already noticed, there is no distinct mineralogical or palæontological connexion. The nummulites found in No. 8 in the middle of this lower Khirthar group comprise *N. obtusa*, *N. granulosa*, *N. leymerici*, *N. spira*, and other species common in the Khirthar limestone itself.

It is probable that the beds below the Khirthar limestone extend throughout a large tract in Baluchistán, on the west side of the Khirthar range, for similar beds are seen, from the crest of the hills, cropping out to the westward as far north as Dháryáro and Kutto-jo-Kabar (the dog's tomb), the culminating point of the range due west of Lárkána. Again, west of the Habb river, forming the boundary of Sind near the sea, the whole Khirthar formation appears composed of shales, marls and sandstones, closely resembling in character those of the lower Khirthar group west of Upper Sind, and an enormous thickness of similar beds is found extensively developed in Makrán.[1]

Khirthar group.—Although this group, named from the great frontier range of hills already noticed, is, when the underlying shales and sandstones are excluded, inferior in total thickness to several

[1] Eastern Persia, vol. ii., pp. 460, 473.

other sub-divisions of the tertiary series in Sind, it comprises by far the most conspicuous rock, the massive nummulitic limestone. Of this formation all the higher ranges in Sind consist. It forms the crest of the Khirthar throughout, and all the higher portions of the Laki range, of the Bhit range south-west of Manchhar lake, and of several smaller ridges, and consists of a mass of limestone, varying in thickness from a few hundred feet in Lower Sind to about 1,000 or 1,200 at the Gáj river, and probably 2,000, or even 3,000, farther north. The colour is usually pale, either white or grey, sometimes, but less frequently, dark grey; the texture varies from hard, close, and homogeneous, breaking with a conchoidal fracture, to soft, coarse and open. Ordinarily, the nummulitic limestone is tolerably compact, but not crystalline, and chiefly composed of *Foraminifera*, especially *Nummulites*, whole or fragmentary; corals, sea-urchins and mollusks also abound, but the two latter very frequently only weather out as casts.

Throughout Northern Sind, except near Rohri, no beds are seen beneath the Khirthar limestone, and the rocks which crop out west of the Sind frontier from beneath the main limestone band have already been described. The remarkable range of low hills, surrounded by Indus alluvium, and extending for more than 40 miles south from Rohri, consists of nummulitic limestone having a low dip to the westward, and beneath the limestone forming the eastern scarp of the hills, on the edge of the alluvial plain, a considerable thickness of pale-green gypseous clays is exposed, with a few bands of impure dark limestone and calcareous shale. No *Foraminifera* have been found in these beds, although *Nummulites* abound in the limestone immediately overlying; several species of mollusca occur, but none are characteristic, and it is far from clear whether the green clays and their associates are merely thick bands intercalated in the limestone, or whether they belong to a lower group. Probably these argillaceous beds of the Rohri hills represent some of the marls, shales and clays forming the lower portion of the upper Khirthar group on the Gáj river.

In some places west of Kotri, a band of argillaceous and ferruginous rock is found close to the base of the Khirthar group. This rock weathers into laterite; it is mainly composed of brown hæmatite, and appears to be found over a considerable area near Kotri and Jhirak. It is impossible to avoid suggesting its identity with the ferruginous lateritic bed found in a similar position in Guzerat, Cutch, the Salt range, and the Sub-Himalayan region.

It has already been mentioned that in the Laki range the nummulitic limestone rests unconformably on the Ranikot group. The Khirthar group here cannot be much more than 500 or 600 feet thick, and

consists entirely of limestone. To the south-east, towards Kotri and Tatta, there is no unconformity between the Ranikot and Khirthar groups, but on the contrary there is an almost complete passage between the two, and the limestone of the latter becomes much split up and intercalated with shales and sandy beds. This is even more the case further to the south-east in Cutch,[1] where, as was noticed on a previous page, the whole group consists of comparatively thin beds of limestone, interstratified with shales. To the south-west, near the Habb river, the massive limestone dies out altogether, and although it is well developed in the southernmost extremity of the Khirthar range near Karchat, about 50 miles south of Sehwan, it disappears entirely within a distance of 12 or 14 miles, and in the ranges on the Habb river is entirely replaced by shaly limestones, shales, and thick beds of sandstone. Some rather massive beds of nummulitiferous dark-grey limestone, very different in character from the pale-coloured Khirthar limestone, are found west of the Habb, but their precise position in the series is not known, and the rocks appearing from beneath the Nari group, in the place of the Khirthar limestone, consist of shales and sandstones, with some calcareous bands abounding in nummulites, and closely resembling, both in character and in the species of *Foraminifera* they contain, the nummulitic shales beneath the massive limestone on the Gáj river. It is not known to what extent the typical Khirthar limestone is developed in Baluchistán; around Kelat, to the northward, this band appears to be extensively exposed, but to the westward, near Gwádar, the rocks supposed to represent the older tertiary beds consist of an immense thickness of shales, shaly sandstones, and unfossiliferous calcareous bands, resembling the lower Khirthars of the Gáj, and the beds of the Habb valley, and limestones with nummulites are of unfrequent and local occurrence. It is thus evident that the Khirthar limestone, although it is so conspicuous in most parts of Sind, and although it attains a considerable thickness, is not by any means universally distributed.

Palæontology.—The most characteristic fossils[2] of the Khirthar group are *Nummulites* and *Alveolina;* neither the genera, nor, as a rule,

[1] See *ante*, p. 345.

[2] The following fossils from the eocene formations of Western India are figured on plate XV:—

Fig. 1. *Voluta jugosa.*
„ 2. *Nerita schmedeliana*, 2a. cast of the same, half natural size.
„ 3. *Pecten labadyei.*
„ 4. *Vulsella legumen.*
„ 5. *Echinolampas discoideus*, ½ size.
„ 6. *Eurhodia morrisi.*
„ 7. *Orbitoides papyracea.*
„ 8. *Orbitoides dispansa.*
„ 9. *Alveolina spheroidea,*
„ 10. *Nummulites garansensis.*
„ 11. *N. sublævigata.*
„ 12. *N. ramondi.*
„ 13. *N. obtusa.*
„ 14. *N. granulosa,*
„ 15. *N. leymerici.*

the species are peculiar, but the extraordinary abundance of individuals renders it usually easy to recognise even small fragments of the rock by the organisms preserved in it. The following is a list of the commonest or most important fossils :—

GASTEROPODA.

Ovulum murchisoni, and other species.
Cerithium cf. *giganteum*.
Nerita schmedeliana, Pl. XV., fig, 2, 2*a*.

LAMELLIBRANCHIATA.

Pholadomya halaensis.
Corbula subexarata.
Cardita mutabilis.
C. subcomplanata.
Lucina gigantea.
Astarte hyderabadensis.
Crassatella sindensis.
C. halaensis.
Vulsella legumen, Pl. XV., fig. 4.
Ostrea vesicularis, var. (*O. globosa*, Sow.)

ECHINODERMATA.

Brissopsis scutiformis.
B. sowerbyi ?
Schizaster, sp.
Eupatagus avellana.
Fibularia, sp.
Amblypygus, sp.
Conoclypeus pulvinatus.
Eurhodia calderi.
Echinolampas discoideus, Pl. XV, fig, 5.
E. sindensis.

FORAMINIFERA.

Orbitolites complanata.
Orbitoides dispansa, Pl. XV, fig. 8.
Patellina cooki.
Alveolina ovoidea.
A. spheroidea, Pl. XV, fig. 9.
Nummulites obtusa, Pl. XV, fig. 13.
Nummulites ramondi, Pl. XV, fig. 12.
N. biaritzensis.
N. beaumonti.
N. vicaryi.
N. granulosa, Pl. XV, fig. 14.
N. leymerici, Pl. XV, fig. 15.

Many of the species named, and the foraminifera especially, are characteristically eocene, and there can be no question that the nummulitic limestone of India is a continuation of the same formation in Europe. Several species pass from the Ranikot beds into the Khirthar group; indeed, the principal palæontological differences between the two may be due to a change in conditions, the Khirthar being apparently a deeper water deposit than the Ranikot group.

Nari group.—The series of tertiary rocks above the Khirthar nummulitic limestone is superbly developed and very well seen in the hills on the frontier of Upper Sind, the culminating ridge of which is known as the Khirthar. The names of the tertiary groups over-

lying the nummulitic formation have consequently been derived from places in this range, and the Nari group takes its title from a stream which traverses the lower portions of the range, composed almost entirely of Nari beds, for a considerable distance, and issues from the hills nearly west of Johi, and west by north of Sehwan. The present sub-division comprises at the base the uppermost bands of limestone containing *Nummulites;* the species, however (*N. garansensis*, Pl. XV, fig. 10, and *N. sublævigata*, ib., fig. 11), being distinct from those so commonly found in the Khirthar sub-division, and the limestone itself being usually distinguished from that of the Khirthar group by its yellowish-brown colour, and by being in comparatively thin bands interstratified with shales and sandstones. Several other fossils, too, besides the nummulites, differ from those in the Khirthar beds. Not unfrequently, however, there is an apparent passage from the white or greyish-white Khirthar limestone into the yellow or brown Nari rock, and the two groups appear always to be perfectly conformable, but no intermixture of the characteristic species of nummulites has been detected, and the division between the Khirthar and Nari beds can always be recognised by the fossil evidence.

In some places the lower Nari beds consist almost entirely of brown and yellow limestones, but more frequently the limestone bands are subordinate; dark shales, and brown rather thinly-bedded sandstone forming the mass of the rocks. The limestone bands are often confined to the base of the group, and always diminish in abundance and thickness above, although they are occasionally found as much as 1,500 feet above the top of the Khirthar. The shales and fine sandstones, with occasional bands of limestone, constitute the lower Naris, and pass gradually into the coarser, massive, thick-bedded sandstones forming the greater portion of the group, and attaining a thickness of 4,000 or 5,000 feet on the flanks of the Khirthar range. With the sandstones a few bands of clay, shale, or ironstone, are interstratified, and bands of conglomerate occasionally occur. The Nari beds in their typical form extend throughout the eastern flank of the Khirthar range, and occupy a belt of varying width, from one or two to as much as 10 miles in breadth, between the underlying Khirthar and the overlying Gáj beds.

On the western side of the Bhagotoro hills, 4 or 5 miles south of Sehwan, there is a break in the Nari beds, and some variegated shales, clays and sandstones, richly tinted in parts with brown and red, and representing the massive sandstones of the upper Nari group, rest unconformably on the denuded edges of the lower Nari brown limestones and shales. The break is evidently local. To the east of the

Laki range the Nari beds are entirely wanting, and it appears very possible that they have never been deposited in this portion of the Indus valley. From the neighbourhood of Sehwan to Jhirak, Manchhar beds rest, with more or less unconformity, on the Khirthar, a very faint and imperfect representative of the Gáj group occasionally intervening. But west of the Laki range, throughout Lower Sind, the Nari beds are found exposed almost wherever the base of the Gáj group is seen; they increase in thickness to the westward, and the Habb valley, from the spot where the river first forms the boundary of British territory to the sea, consists entirely of these strata. There is, however, in this part of the country no longer any such marked distinction between the sub-divisions of the tertiary series as is found in the Khirthar range. The disappearance of the Khirthar limestone has already been mentioned, and with it the lower Nari limestones with *Nummulites garansensis* and *N. sublævigata* also disappear, so that it is no longer possible to draw a distinct line between the two groups, for the shaly beds at the base of the Naris are undistinguishable from similar rocks in the Khirthars. The calcareous shales, with the characteristic Khirthar nummulites, below, and the massive Nari sandstones above, are still recognisable, and the two groups can consequently still be traced, although the dividing line between them is obscured. Beds of brown limestone, too, full of *Orbitoides papyracea* (or *O. fortisi*, Pl. XV, fig. 7), a fossil closely resembling a nummulite, and associated in abundance with *N. garansensis* in the typical lower Nari limestones, occur in the Nari beds of the Habb valley; but instead of being found at the base, they appear in the middle of the group. Again, just as at the base of the Naris, there is a difficulty in distinguishing them from the Khirthar, so the beds at the top of the former group can only be separated by an arbitrary line from the overlying Gáj beds. In the Khirthar range the upper boundary of the Nari group, although there is no unconformity, is distinct and definite, limestones with marine fossils of the Gáj group resting immediately upon the upper Nari sandstones. But in Southern Sind bands of limestones, or calcareous sandstone, with marine fossils, some of which are well-marked Gáj species, occur in the upper part of the Nari group, whilst limestone bands with the Nari *Orbitoides papyracea* are found in the Gáj.

Palæontology.—The sandstones, which form so large a portion of the Nari group, have hitherto proved destitute of animal remains, and in the typical area in Upper Sind, no beds with marine fossils are intercalated in the upper portion of the group, but the occasional interstratifications of shales and clays often contain fragments of plants, and some ill-marked

impressions, probably due to fucoids, have been found in the sandstones themselves. There appears a probability that these sandstones may be of fluviatile and not of marine origin.

In the limestones towards the base of the Nari group, many marine fossils have been obtained, the following being some of the more important:—

GASTEROPODA.

Terebellum obtusum.
Cypræa nasuta.
Voluta jugosa, Pl. XV, fig. 1.
V. dentata.
Triton davidsoni.
Natica patula.
N. sigaretina.
Siliquaria granti.
Solarium affine.
Trochus cumulans.
Phasianella oweni.

LAMELLIBRANCHIATA.

Corbula harpa.
Venus granosa, Pl. XVI, fig. 7.
Cardium triforme.
Pecten labadyei, Pl. XV, fig. 3.
Ostrea flabellula.

ECHINODERMATA.

Schizaster beloutchistanensis.
Eupatagus rostratus.
Echinolampas, sp.
Clypeaster profundus.
Cœlopleurus forbesi.
Cidaris verneuilli.

ANTHOZOA.

Trochocyathus burnesi.
Montlivaltia vignei.

FORAMINIFERA.

Nummulites garansensis, Pl. XV, fig 10.
N. sublævigata, Pl. XV, fig. 11.
Orbitoides papyracea, Pl. XV, fig. 7.

Although some species pass from the Khirthar, and even from the Ranikot group into the Nari beds, the fauna is chiefly distinct and marks a higher horizon. The most marked change is perhaps in the *Foraminifera*, because they are so abundant and characteristic; whole beds of limestone towards the base of the Nari group being entirely made up of *Nummulites garansensis*, *N. sublævigata* and *Orbitoides papyracea*, the last named frequently of large size, some specimens being two to three inches in diameter; yet every species is distinct from those occurring in the Khirthar group. One of these species of *Nummulites*, *N. garansensis*, is of importance, because it occurs in Europe, as in Sind, in the highest strata characterised by the abundance of the genus, those beds being at the base of the miocene. *Nummulites sublævigata* is peculiar, so far as is known, to India.

Several of the *Mollusca* and *Echinodermata* of the Nari beds also, such as *Siliquaria granti*, *Solarium affine*, *Venus granosa*, *and Clypeaster*

profundus, shew distinctly miocene affinities, and some of these pass up into the Gáj group. But at the same time there are so many eocene forms present, such as *Natica patula*, *N. sigaretina*, *Ostrea flabellula*, *Voluta jugosa*, &c., that it is somewhat difficult to decide to which subdivision the Nari beds should be assigned. They may, perhaps, occupy an intermediate position, similar to that of the oligocene of continental geologists.

Gaj group.—Upon the Nari group, almost throughout Sind, there is found resting a mass of highly fossiliferous limestones and calcareous beds, usually more or less shaly, always distinctly stratified, and easily distinguished from the limestones of the older tertiary formations by the absence of nummulites. A superb section of the strata forming this group is exposed on the banks of the Gáj river, the only stream which cuts its way through the Khirthar range, and in the neighbourhood of which, west of the range, the fine section of lower tertiary and cretaceous beds already noticed is exposed. From this river the present group derives its name.

On the eastern flanks of the Khirthar range in Upper Sind, the Gáj group forms a conspicuous ridge, the hard dark-brown limestone bands near the base of the formation resisting the action of denudation far more than the soft sandstones of the Nari beds, and rising every here and there into peaks of 1,000 and 1,500 feet, or even more, escarped to the westward, and sloping to the east; Amru, the highest summit of the Gáj ridge, being 2,700 feet above the sea. Still, the limestone bands, although so conspicuous, are subordinate, the greater part of the group consisting of sandy shales, clays with gypsum, and, towards the base, sandstones. Many of the bands of limestone appear very constant in position, and may be traced for a long distance; as a rule, they are dark-brown in colour, but one bed is white and abounds in corals and small *Foraminifera* (*Orbitoides*), whilst some of the darker bands contain *Echinodermata* in large quantities.

The uppermost portion of the group is usually argillaceous, being chiefly composed of red and olive clays with white gypsum, and these beds pass gradually into precisely similar strata belonging to the overlying Manchhar group. The passage beds contain, amongst other fossils such as *Turritella angulata*, Pl. XVI, fig. 2, and forms of *Ostrea* and *Placuna*, the following:—

Corbula trigonalis, Pl. XVI, fig. 8.
Lucina (Diplodonta) incerta.
Tellina subdonacialis.
Arca larkanensis, Pl. XVI, fig. 6.

All of these have allies living in estuaries at the present day; *Arca granosa*, a recent representative of *A. larkanensis*, being one of the

commonest and most typical of Indian estuarine mollusca. To these estuarine passage beds further reference will be made presently when the relations of the Manchhar to the Gáj beds are discussed.

The Gáj beds at the Gáj river are very nearly 1,500 feet thick, but they appear to be less developed to the northward in the Khirthar range, and not to be much more than half the thickness named west of Lárkána, where, however, they are nearly vertical, and have probably suffered from pressure. In Lower Sind, the Gáj group, like the Nari, disappears to the eastward of the Laki range, where it is either entirely wanting, or else represented by a thin band containing one of the characteristic fossils, *Ostrea multicostata* (Pl. XVI, fig. 3), at the base of the Manchhar group. There is, however, a very large area of Gáj beds north and north-east of Karáchi, and the appearance of the formation here is somewhat different from what it is in the Khirthar range, for the greater portion of the group consists of pale-coloured limestones, almost horizontal, or dipping at very low angles, and to the east of the Habb valley forming plateaus 400 or 500 feet high bounded by steep scarps, which rise from the low ground of the soft Nari sandstones. A low range of hills, formed of Gáj beds, extends to the south-west, past the hot spring at Magar or Mangah Pir, to the end of the promontory known as Cape Monze, west of Karáchi, and the same beds form the low hills east and north-east of the town, and furnish the materials of which the houses in Karáchi are mostly built. A small island called Churna, in the sea, west of Cape Monze, also consist of Gáj rocks. To the northward the Gáj area of lower Sind extends with very irregular outline to the neighbourhood of Tong and Karchat, almost due west of Hála, and there are several outliers farther north, connnecting the southern portion of the group with the typical outcrop in the Khirthar range. East of Karáchi, also, Gáj beds extend in the direction of Tatta, until they disappear with the other tertiary rocks beneath the alluvium of the Indus. As was shewn in a previous chapter, the Gáj group of Sind appears to be represented in Cutch by a highly fossiliferous belt, containing most of the typical mollusca, echinoderms, &c. It is quite possible that the present group, as well as the Nari, never was deposited in the neighbourhood of Kotri and Jhirak.

It has been already stated that the Gáj beds, throughout the greater portion of the Khirthar range, rest conformably upon the Nari group, although there is a change in mineral character, and that, in lower Sind, the passage from one group into the other is gradual, calcareous bands with Gáj fossils, such as *Ostrea multicostata* and *Pecten subcorneus*, being found interstratified with the uppermost Nari sandstones. At one place

however, near Tandra Ráhim Khán, west by north of Sehwan, the outcrop of the Gáj beds, here dipping at a high angle to the westward, runs nearly in a straight line across the mouth of a valley, composed of a deep synclinal of the Nari group between two anticlinal ridges of Khirthar limestone. As the Gáj beds do not share the synclinal curve of the Naris, it is difficult to see how the two can be conformable; but an examination of the boundary between the two groups failed to shew any clear evidence of unconformity. There are, however, some places south of Sehwán where the Gáj group overlaps the Nari beds and rests upon the Khirthar limestone, but it must be recollected that the Gáj group is itself overlapped by Manchhar beds in the immediate neighbourhood.

Palæontology.—The following[1] is of course a very imperfect list of the animal remains found in this richly fossiliferous group, only the more important or common forms being noticed:—

CRUSTACEA.

Palæocarpilius rugifer.[2]
Typilobus, sp.
Balanus sublævis.

GASTEROPODA.

Buccinum cautleyi.
B. vicaryi.
Vicarya verneuilli, Pl. XVI, fig. 1.
Turritella angulata, Pl. XVI, fig. 2.

LAMELLIBRANCHIATA.

Kuphus rectus (*Serpula recta*, Sow.).
Corbula trigonalis, Pl. XVI, figs. 8, 8*a*.
Venus granosa, Pl. XVI, fig. 7.
V. cancellata.
Tapes subvirgata.
Cardium anomale.
Astarte hyderabadensis.
Dosinia pseudoargus.
Arca kurracheensis, Pl. XVI, figs. 5, 5*a*.
Arca peethensis.
A. larkhanensis, Pl. XVI, fig. 6.
Pectunculus pecten.
Pecten subcorneus.
P. bouei.
P. favrei, Pl. XVI, fig. 4.
Spondylus tellavignesi.
Ostrea multicostata, Desh., Pl. XVI, figs. 3, 3*a*.

ECHINODERMATA.

Schizaster, sp.
Maretia cf. *planulata*.
Meoma, sp.
Breynia carinata, Pl. XVI, fig. 9.
Echinolampas jacquemonti.
Echinolampas spheroidalis.
Echinodiscus, sp., Pl. XVI, fig. 10.
Clypeaster profundus.
C. depressus, Pl. XVI, fig. 11.
Cœlopleurus forbesi.

[1] The following fossils from the miocene beds of Sind are figured on Plate XVI:—

Fig. 1. *Vicarya verneuilli*.
„ 2. *Turritella angulata*.
„ 3. *Ostrea multicostata*, Desh.
„ 4. *Pecten favrei*.
„ 5. *Arca (Paralellopipedum) kurracheensis*.
Fig. 6. *Arca (Anomalocardia) larkhanensis*.
„ 7. *Venus granosa*, ½.
„ 8. *Corbula trigonalis*.
„ 9. *Breynia carinata*.
„ 10. *Echinodiscus*, sp.
„ 11. *Clypeaster depressus*, ½.

[2] Stoliczka: Pal. Ind., Ser. VII, p. 8, Pls. IV, V.

ANTHOZOA.

Pachyseris murchisoni.	*Cladocora haimei.*
Hydnophora plana and other species.	*Mycedium costatum.*

FORAMINIFERA.

Operculina canalifera.	*Orbitoides papyracea.*

The commonest and most characteristic fossils of this group are *Ostrea multicostata* [1] and *Breynia carinata.* There cannot be any question that the Gáj fauna is newer than eocene; some of the species are recent (for instance, *Dosinia pseudoargus* is identical with the recent *D. exasperata,* Chemn.), and it is probable that many others, when they are compared with recent forms more carefully than has hitherto been done, will prove to be the same as living species. Several genera, too, as *Maretia, Breynia, Meoma, Echinodiscus, Cladocora,* and *Mycedium,* are rare or unknown in the older tertiaries, and there is almost a complete disappearance of eocene forms, very few species being common to the Nari beds even. The chief doubt is whether the Gáj should not be considered as upper miocene.

The only mammal yet obtained from the Gáj beds is *Rhinoceros sivalensis*—a species found also in the Siwaliks.

Manchhar group.—The highest sub-division of the Sind tertiary series has been named from a large lake, the Manchhar, a few miles west of Sehwan. The group doubtless represents generally the far better known Siwaliks of Northern India, and it is probable that the upper and lower limits of the two may be the same, but the fossiliferous bands are at different horizons.

The Manchhar group of Sind consists of clays, sandstones, and conglomerates, and attains in places a thickness of but little, if at all, less than 10,000 feet on the flanks of the Khirthar range. Although it is difficult to draw an absolute line between the sub-divisions, the whole group may be divided, wherever it is well exposed, into two portions; the lower consisting mainly of a characteristic grey sandstone, rather soft, moderately fine grained, and composed of quartz, with some felspar and hornblende, together with red sandstones, conglomeratic beds, and, towards the base, red, brown, and grey clays; the latter, however, being much less largely developed than in the upper sub-division. The conglomeratic beds chiefly contain nodules of clay and of soft sandstone, apparently derived from beds precisely similar to those of the Manchhars themselves; so far as has been observed, these conglomerates do not contain fragments derived from the older tertiary rocks, no pebbles either

[1] It is not quite certain whether this species is identical with the European form, but it is certainly the shell figured by Messrs. D'Archiac and Haime. There is another species known by the same name and found in triassic beds in Europe.

of the characteristic Gáj limestones or of the still more easily recognised nummulitic limestone of the Khirthars having been noticed in the beds of the lower Manchhars, although both abound in the upper strata of the group. These conglomeratic beds of the lower Manchhars are frequently ossiferous, the bones and teeth contained in them being, however, usually isolated and fragmentary.

The upper Manchhar sub-division, where it is best seen, on the flanks of the Khirthar range, west of Lárkána, is thicker than the lower, and consists principally, towards the base, of a great thickness of orange or brown clays, with subordinate bands of sandstone and conglomerate. The sandstones are usually light-brown, but occasionally grey, like the characteristic beds of the lower sub-division. The higher portion of this upper sub-group contains more sandstone and conglomerate, and the whole is capped by a thick band of massive coarse conglomerate, which throughout Upper Sind forms a conspicuous ridge along the edge of the Indus alluvium. This conglomerate contains numerous large pebbles of nummulitic and Gáj limestone, together with fragments of quartzite and other rocks of unknown origin. Throughout the conglomeratic beds of the upper Manchhars, pebbles of nummulitic limestone and of the brown Gáj limestone occur, shewing that these older tertiary beds must have been upheaved and denuded in the later Manchhar period, although there is a complete passage between the Gáj beds and the lower Manchhars.

There appears, however, good reason for supposing that some disturbance of the older rocks took place before the deposition of the lower portion of the Manchhar group. To the east of the Laki range the Manchhar beds, themselves disturbed, rest unconformably on the Khirthar group, the beds of which are vertical in many places, so that it is manifest that the Khirthars had in this locality been upheaved before the deposition of the Manchhars. The presence in this locality of the lower portion of the latter group appears to be proved by the occurrence of teeth and bones of the same mammals as are found in the lower Manchhars elsewhere.

It is evidently far from improbable that the Manchhar group of Sind should be sub-divided into two distinct groups, the upper being perhaps the equivalent of the typical Siwaliks. Only a few fragments of bones, too imperfect for determination, have, however, hitherto been found in the upper Manchhars, so that no clue to the age of the sub-division is afforded by fossil remains. There is also a possibility that the coarse conglomerate capping the whole tertiary series should be classed apart from the underlying beds, although it appears to pass into them. The only reason for

distinguishing the upper conglomerate, apart from its great coarseness and thickness, is that it, and it alone, exhibits some slight connection in its development with the existing features of the country; at least the conglomeratic band appears to be much thicker at the spot where it is traversed by the Gáj river than it is to the northward or to the southward, and this increase in thickness may be due to an accumulation of pebbles brought down by a stream which occupied in upper Manchhar times the same position as the Gáj now does. A similar increase in the development of conglomerate near the course of the present rivers will be noticed in a subsequent chapter in the case of the Sub-Himalayan Siwaliks. It is, however, manifest that a great part of the disturbance which has caused the elevation of the Khirthar range is of later date than the Manchhar conglomerate, because that conglomerate has been tilted up at high angles, and appears to dip conformably with the older tertiary rocks. Nevertheless it is true that, as has been shewn in the last paragraph, there must have been some change of level before the Manchhars were deposited, and it is also true that there is in places an apparent passage from the upper Manchhar conglomerate into the gravels of the slope, on the edge of the alluvium, but the latter may simply be due to the reconsolidation of pebbles derived from the conglomerate itself; and if the amount of disturbance in the interval between the upper and lower Manchhar periods was considerable, the evidence of such a break should be more conspicuous than it is. On the whole, it appears evident that the great period of disturbance which terminated the tertiary epoch in Sind commenced during the deposition of the Manchhar beds, or probably even earlier, but that far greater changes took place after the highest Manchhar strata had been deposited than during the period of their deposition.

In one case a few estuarine fossils were found, near the Nari stream, in a Manchhar bed 300 or 400 feet above the base of the group. The only form recognised was *Corbula trigonalis*, already mentioned as characteristic of the estuarine passage beds between Gáj and Manchhar. With this exception, and that of some rolled oyster-shells possibly derived from a lower formation, no marine or estuarine fossils have been observed in the Manchhar beds of Upper Sind, above the passage beds at the base of the group, and there appears every reason to believe that the group is of fluviatile origin. The form of the pebbles in the conglomerate of the upper Manchhars is that of stream-worn, and not that of sea-worn fragments; they approach an oblate rather than a prolate spheroid. Still the amount of rounding is such as could only have been produced by a rapid stream.

In Lower Sind, however, there is a very considerable intercalation of marine or estuarine beds with the Manchhars, and this evidence of deposition in salt water increases in the neighbourhood of the present coast. Around Karáchi, beds of oysters, and sometimes of other marine or estuarine shells, are found not unfrequently interstratified with the Manchhar group. There is also some change in mineral character, the sandstones becoming more argillaceous and being associated in places with pale grey sandy clays and shales. The passage into the Gáj beds is very gradual, calcareous bands with Gáj fossils, such as *Ostrea multicostata* and *Pecten subcorneus*, being found some distance above the base of the Manchhar group.

Although, on account of the change in mineral character, there is, except in the neighbourhood of the coast, no difficulty in drawing a line between Manchhar and Gáj beds, everything tends to shew that there is no break in time between the two, the lower portion of the upper group being an estuarine or fluviatile continuation of the underlying marine beds. But the great thickness of the Manchhar group in Upper Sind alone would suffice to prove that a considerable period of time must have elapsed during the deposition of this formation, and it is far from improbable that the lower Manchhars may be upper miocene, whilst the upper Manchhars are pliocene.

The Manchhar beds extend along the edge of the alluvium, and form a broad fringe to the Khirthar range, throughout Upper Sind, from west of Shikarpur to the Manchhar Lake, but the breadth of the outcrop varies greatly, being as much as 14 miles where broadest west of Lárkána, and diminishing both to the north and south. As already noticed, the Manchhars are thickest just where their outcrop is widest, but the breadth of the area occupied by them is not due simply to their vertical development, but chiefly to their forming a synclinal and anticlinal roll before disappearing beneath the alluvial plain; whereas in other parts of the range the same beds are exposed in a simple section, all the strata dipping to the westward. To the north the section is complicated by faults, but to the south the thickness of the Manchhar group diminishes greatly, and west of Sehwan, near Tandra Ráhim Khán, although both upper and lower sub-divisions of the group are developed, and the uppermost conglomerate is exposed, the whole thickness of the Manchhar strata cannot be much more than about 3,000 feet. The Manchhar beds are seen west, south, and east of the Manchhar Lake; they are well developed, and occupy a large plain to the east of the Laki range, and west of the nummulitic limestone tract near Kotri and Jhirak; they reappear in many places in the different synclinal valleys to the west of

the Laki range, and they occupy a considerable tract of country east and north-east of Karáchi. But throughout these areas in Lower Sind the rocks are not nearly so well seen as to the northward, the soft sandstones and clays of the Manchhar group having been denuded into undulating plains, covered and concealed in general by the pebbles and sands derived from the neighbouring hills, formed of the comparatively hard older tertiary rocks, and it is far more difficult than it is in Upper Sind to distinguish the different portions of the group, or to form a correct idea of the thickness of strata exposed.

Relations to Makran group.—The Manchhar beds extend along the edge of the sea, west of Karáchi, almost to the end of Cape Monze, but no representative of this formation is seen for a considerable distance to the westward of the Cape. The few exposures of rocks seen near the shores of Sonmiani Bay are older tertiary, or perhaps cretaceous, and the greater part of the country consists of alluvium; a low cliff near the coast, north of Gadáni, being composed apparently of sub-recent deposits. But west of Sonmiani Bay, in the neighbourhood of Hingláj, a well-known place of Hindu pilgrimage, there are high hills of hard greyish white marls or clays, usually sandy, often highly calcareous, and occasionally intersected by veins of gypsum. With this clay or marl, bands of shaly limestone, dark calcareous grit and sandstone are interstratified, but they usually form but a small portion of the mass, although their greater hardness renders them conspicuous. This marl formation extends for many hundreds of miles along the coast, and is well seen at Rás Malán, Ormára, Pasni, Gwádar, near Jáshk at the entrance of the Persian Gulf, and on the Persian shores of the gulf itself. The headlands of Rás Malán, Ormára, and Gwádar consist of great horizontal plateaus, surrounded by cliffs of whitish marl or clay, and capped by dark-coloured calcareous grit, Rás Malán especially being a table-land rising abruptly to a height of 2,000 feet from the sea. These remarkable rocks have been called the Makrán group [1] from the name usually applied to the littoral tracts of Baluchistán.

The Makrán group is of purely marine origin, and abounds in mollusca, echinoderms, &c., most of the species apparently being the same as those found in the neighbouring seas at present. The collections made at Gwádar, Jáshk, and other places have not been sufficiently compared to ascertain whether any are common to the Gáj beds of Sind, but by far the greater portion are distinct; none of the characteristic Gáj fossils, such as *Ostrea multicostata, Breynia carinata, Echinolampas jacquemonti*, &c., have been noticed in the Makrán group, and the latter

[1] Rec. G. S. I., V, p. 43; Eastern Persia, II, p. 462.

appears to be of later age than the miocene Gáj beds. Although there is no resemblance between the typical Manchhar beds and the characteristic rocks of the Makrán group, nor, from the widely different conditions under which the two formations must have been deposited, would any similarity in mineral character be probable, some of the soft argillaceous shaly sands in the Manchhar beds near Karáchi closely resemble some similar beds in the Makrán group near Gwádar. As the coast of Baluchistán has never been examined geologically, all that is known of its structure having been ascertained by brief visits to a few points separated from each other by intervals of from 50 to 100 miles, it is uncertain to what extent the rocks of Sind extend to the westward, and whether any representatives of the Gáj group, especially, exist in that direction, but there appears a considerable amount of probability that the marine Makrán group in Baluchistán may represent the fresh-water Manchhars and Siwáliks on the edge of the Indo-Gangetic plain.

Palæontology of Manchhar group.—The only fossil remains of any importance hitherto detected in the Manchhar group are bones of mammalia, and all that have been recognised belong to the lower Manchhars, the upper sub-division of the group, as has already been mentioned, having hitherto furnished only a few bones, in too poor and fragmentary a state of preservation for the species, or even the genera, to be determined. The few estuarine shells which have been found in the lowest Manchhar beds in Upper Sind, and a portion at least of the marine fossils procured from a similar horizon near Karáchi, appear to be Gáj forms, and to indicate a close connection between the lower Manchhars and the underlying group. In places, and especially in the neighbourhood of the Laki range, silicified fossil wood is found in abundance in the Manchhar beds, stems of large trees being of common occurrence. The majority are dicotyledonous, but some fragments of monocotyledons are also found.

The following is a list of the species of *Vertebrata*[1] hitherto identified from the lower Manchhar group: it should perhaps be repeated that the remains are extremely fragmentary, and chiefly consist of single teeth and broken portions of bones. No remains of *Quadrumana, Chiroptera, Insectivora, Rodentia, or Cetacea* have hitherto been found, and the fauna is chiefly remarkable for the prevalence of artiodactyle ungulates, allied to pigs, or intermediate between pigs and ruminants.

[1] These have been named by Mr. Lydekker, Rec. G. S. I., IX, pp. 91, 93, 106; X, pp. 76, 83, 225; XI, pp. 64, 71, 77, 79, &c.; Pal. Ind., ser. X, pt. 2.

MAMMALIA.

CARNIVORA.

Amphicyon palæindicus, Pl. XIX, fig. 4.

PROBOSCIDIA.

Mastodon perimensis, Pl. XVII, fig. 3.	*Mastodon (Trilophodon) falconeri.*
M. latidens, Pl. XVII, fig. 4.	*Dinotherium pentepotamiæ.*

UNGULATA.

PERISSODACTYLA.

Rhinoceros palæindicus.	*Acerotherium perimense.*
* *R.* sp. near *R. deccanensis.*	

ARTIODACTYLA.

Sus hysudricus.	* *Hyopotamus palæindicus.*
* *Hemimeryx*, sp.	* *Hyotherium sindiense.*
* *Sivameryx*, 2 sp.	*Dorcatherium majus.*
Chalicotherium sivalense.	*D. minus.*
Anthracotherium silistrense.	

EDENTATA.

* *Manis sindiensis.*

REPTILIA.

Crocodilus, sp.	*Ophidia*, sp. indet.
Chelonia, sp. indet.	

Species marked with an asterisk have not been found elsewhere. The majority of the genera are extinct; *Rhinoceros, Sus,* and *Manis* being the only living types, and the last named has only been recognised from a single digital phalange, so that the generic identification is far from sufficient. Both *Rhinoceros* and *Sus* existed in miocene times, whilst *Amphicyon, Anthracotherium, Hyopotamus,* and *Dinotherium* are not known to occur in Europe in beds of later date than miocene. The genera *Hemimeryx* and *Sivameryx* are peculiar; both are allied to the Siwalik *Merycopotamus.*

The species found also in the pliocene Siwaliks are *Rhinoceros palæindicus, Acerotherium perimense, Chalicotherium sivalense, Sus hysudricus,* the two species of *Dorcotherium, Mastodon ladidens,* and *Mastodon falconeri;* but as the presence of these forms in the Manchhars is inferred for the most part from fragments, the identifications are by no means quite certain, whilst the general facies of the fauna, the absence of characteristic living forms like *Equus, Bos, Antilope, Cervus,* and *Elephas,* and the presence of several extinct genera not hitherto detected in the Siwaliks, shew that the mammaliferous beds of Sind are of older age than the typical Siwalik strata. It should be recollected, moreover, that the precise horizon at which the Siwalik forms are found is but rarely known with accuracy; that some of the Siwalik strata are as old as the lower Manchhars, if not older, and that a portion at least of the older types of mammals are from

beds low in the Siwalik series. None of the remarkable series of types allied to the giraffes and *Sivatherium*, nor of the peculiar bovine and antilopine forms so characteristic of the Siwalik fauna, have as yet been found in Sind; the only ruminant detected in the Manchhar beds is the miocene *Dorcatherium*, and the place of the more specialised *Pecora* appears to have been occupied by the less specialised even-toed ungulates allied to the pig. While therefore it is probable that some extinct types, such as *Anthracotherium* and *Hyopotamus*, which are not known in Europe above the lower miocene, existed in India at a somewhat later period, together with species which survived till pliocene times, it is evident that the lower portion of the Manchhar group can scarcely be considered of later date than upper miocene. The palæontological evidence is in accordance with the geological, and both shew the close connexion between the lower Manchhar beds and the Gáj group.

Post-tertiary beds.—The post-tertiary formations in the Sind hills are not of sufficient importance to deserve a lengthened description; gravel, sand and clays, brought down by torrents, occupy a large area in the valleys, and frequently form a slope some miles broad, extending from the base of each range of hills, and covering a very large portion of the intervening valleys. The same phenomenon is seen throughout a great part of Western and Central Asia, being more conspicuous on account of the dryness of the climate and the resulting deficiency of forest or dense vegetation; independently, however, of the greater facilities for studying such formations which are afforded by the absence of trees and shrubs, the formation of extensive gravel slopes appears to be characteristic of climates like that of Sind, with a low rainfall, because in such tracts rock detritus accumulates along the bases of hills more quickly than it can be carried away by the streams; the rainfall is sufficient to wash down the disintegrated fragments from the steeper slopes, but not to carry them forward where the fall is more gradual.[1]

The great plain north-east of Karáchi is covered by extensive alluvial deposits, chiefly of gravel and sand; the gravels here, and in many of the valleys in Western Sind, being often consolidated into a hard conglomerate by carbonate of lime derived from the pebbles of limestone, which form the bulk of the detritus. Some oysters of recent species are found in the conglomerates near Karáchi.

Additional notes on Sind tertiary series.—Before quitting the subject of the Sind tertiaries, there are two or three points to which attention may be directed. These points are chiefly of interest with

[1] For further details as to these gravel slopes, see Q. J. G. S., 1873, p. 496; Eastern Persia, II, p. 465; and also Drew, Q. J. G. S., 1873, pp. 445, &c.

regard to the geology of more extensive areas, but the knowledge, gained in the last few years, of the sequence in Sind, and of the peculiarities of the upper mesozoic and tertiary series there exposed, together with the great imperfection of our acquaintance with all the neighbouring regions, renders it desirable that these geological features, although they may not be peculiar to the Sind area, should not be overlooked when the characters of the region are compared with those of other parts of India.

Absence of general breaks below pliocene.—The first of these points is the general conformity of the whole series from cretaceous (probably upper cretaceous) to pliocene. The lowest bed, the hippuritic limestone, passes into the cretaceous sandstones, and these again into the olive shales with *Cardita beaumonti*. The Deccan trap and the Ránikot beds at the base of the eocene period follow in regular and conformable succession, and the break, shewn by the Khirthar limestones resting on the denuded edges of the upper Ranikot beds in the Laki range, is merely local, for a few miles to the south-east the two formations pass completely into each other. At the top of the Khirthar limestones also, although there is a sudden and abrupt change in the fauna, no unconformity has been detected at the base of the Nari group, whilst Nari beds in many places, and especially in South-Western Sind, pass uninterruptedly into the miocene Gáj beds, and there is again a complete passage from the latter into the Manchhar group. In the middle of the Manchhar formation there may be a break proved by some slight indications of unconformity and by the appearance of detritus derived from middle and lower tertiary beds in the upper sub-division, but the unconformity, if any exist, is probably local.

Great post-pliocene disturbance.—Here, however, the sequence ends, and, in the evidence of great disturbance having taken place in Western Sind since the upper Manchhar beds were deposited, there is an abrupt and startling change from the phenomena exhibited on the other side of the Indus valley. We are in fact brought into the presence of one of the great facts which divide with so trenchant a line the geology of the Indian Peninsula from that of neighbouring countries. The eocene nummulitic limestone, even in the middle of the Indus valley around Sukkur and Rohri, never dips at more than 5°, and rarely at more than 1° or 2°; the tertiaries of Cutch, Kattywar and Surat pass upwards almost without a break into the coast alluvium; the laterite of Western India, probably of tertiary age at least, lies undisturbed upon the flat cretaceous basalts; and the difficulty in drawing a line between older and newer forms of laterite—a difficulty so frequently pointed out in the

fifteenth chapter of the present work—alone suffices to shew how destitute of violent disturbance the geological history of peninsular India has been in cænozoic times. It is unnecessary here to do more than refer to the older mesozoic and palæozoic rocks of the Indian Peninsula, but it is a fact that the pliocene beds of Sind and the Himalayas are more disturbed than the ancient azoic Vindhyans of Bundelkhand. The uppermost Manchhar rocks on the edge of the alluvial Indus plain are frequently vertical, and rarely dip at lower angles than 30° or 40°, and it is manifest that the great anticlinal ridges of the Sind mountains have been mainly formed in post-pliocene times.

In the few notes on the physical geography of Sind at the commencement of the present chapter, it was shewn that the ranges of hills in the province are simple anticlinals with paralled axes, all running nearly north and south. This probably proves that the action of disturbance has been unusually simple, and has consisted of a distinct lateral thrust from one direction. The change of direction to the westward in Baluchistán, and to the northward in the Punjab, has been noticed elsewhere.

Alternation of marine and fresh-water beds.—The cretaceous rocks appear to have been marine, with the possible exception of the unfossiliferous sandstones above the hippuritic limestone, but at the base of the Sind tertiary rocks, in the Ranikot beds, proofs of the immediate neighbourhood of land are afforded by the presence of terrestrial plants. It is probable that the thin band of Deccan trap at the base of the Ranikot group was of subaërial origin in Sind as elsewhere, and that the lower Ranikot beds themselves are fluviatile. The upper portion of the Ranikot group, the whole of the Khirthar and the lower Nari beds are marine, and the nummulitic limestone may have been deposited far from land, whilst it is certain that a considerable portion of this limestone formation is too pure to have accumulated in a sea into which sediment in any quantity was poured by rivers or washed from a coast line. But, as has been shewn above, the Khirthar limestone in Lower Sind contains intercalated sandstones and shales, shewing the admixture of detritus derived from land, and the great limestone band itself disappears in the south-western part of the province near the Habb river. The thick upper Nari sandstones, and the still thicker Manchhars have, again, the character of fluviatile deposits, but the intervening Gáj group is marine and in part perhaps estuarine.

Thus throughout the tertiary series of Sind there is evidence of frequent alternations of marine and terrestrial conditions, the last marine beds known being of miocene date. It will be shewn in subsequent chapters

that to the northward, on the flanks of the Himalayas, the tertiary marine beds tend to disappear or diminish, even the nummulitic limestone, the only marine formation which appears to be persistent throughout the greater part of the extra-peninsular area, being much less developed in the Sub-Himalayan ranges than it is in the neighbourhood of the lower Indus valley.

CHAPTER XX.

EXTRA-PENINSULAR AREA.

THE PUNJAB HILLS WEST OF THE JHELUM.

Physical geography and general features — Geological data — General geological features — Rock-groups of Salt Range — Rock-groups of Hazára and the Northern Punjab — Abnormal boundary of upper tertiaries — Azoic and palæozoic rocks of Salt Range, &c. — Salt marl — Purple sandstone — Silurian ? — Magnesian sandstone — Speckled sandstone — Carboniferous — Mesozoic rocks of Salt Range, &c. — Ceratite beds — Pseudomorphic salt crystal zone — Jurassic or variegated group — Cretaceous (neocomian) — Olive group.

Physical geography.—Passing northward from Sind to the Punjab, the physical features of the country at first undergo little or no change. The South-Western Punjab near the Sind frontier consists, like Sind itself, of the alluvial plain of the Indus, bounded to the westward, for the most part beyond the limits of the province, by a range of tertiary hills, and to the eastward by a sandy desert. Farther north the alluvial tract expands into the great plain of the five rivers, the rocky boundary, known as the Sulemán Range, continuing to the westward. A little beyond the thirty-second parallel of north latitude, however, a series of curved hill ranges, of which the most important, between the Indus and Jhelum, is known as the "Salt Range," crosses the province from Shekh Budín, a little north of Dera Ismail Khan, to Jhelum, and to the northward of these ranges, which cross the Indus at Kálabágh, a tract of more or less hilly country extends to the foot of the Himalayas, and of the great mountain ranges between the Himalayas of Western Kashmir and the Hindu Kush.. But this tract may again be sub-divided into three high level plains, more or less broken up by ravines, and separated from each other by ranges of hills. The south-eastern plain extends from the Salt Range to beyond Ráwalpindi, and closely approximates in dimensions with the basin of the river Soán, a tributary joining the Indus a little above Kálabágh. This plain is sometimes known as the Potwár or the Ráwalpindi plateau; it extends from the Indus nearly to the Jhelum; it has a superficial area of about 7,000 square miles, and a general elevation of about 1,000 feet above the Indo-Gangetic plain to the south of the Salt Range. The surface is greatly cut up by deep ravines in the soft Siwalik beds, of which almost the whole area is composed. North of this southern plain there is a series of hill ranges

known as Márgalla, Chitapahár, Cherát, &c., which have a general east and west (or east by north to west by south) direction, and connect the Murree and Hazára with the Afridi mountains. These hill ranges traverse the Northern Punjab south of Attock, and repeat, though on a diminished scale, the remarkable curves of the Salt Range and Chicháli or Shingarh hills. North of the Cherát and Afridi hills is the alluvial plain of Pesháwar, and this again is bounded on the north by the hills of Swát and Yusafzai, the geology of which is unknown.

A third plain, more to the westward, of smaller extent than either of the former, exists in the neighbourhood of Bannu (Bunnoo). It is close to the northern continuation of the Sulemán Range, and is bounded to the northward by ranges of hills having a general east and west direction in the Bahádur Khel and Waziri country in Kohát, and to the east and south by the trans-Indus continuation of the Salt Range, known under a variety of names, such as Chicháli or Shingarh, Káfirkot, Shekh Budín, &c., none of which, however, appear to have more than a local value.[1] The Bannu plain comprises about 1,500 square miles; it is about 1,200 feet above the sea, and is drained by the Kurram (Koorum) river and its tributaries.

For the purposes of the present work, the boundary between the Punjab and Himalayan areas will be understood as coinciding with the course of the Jhelum below the junction with the Kishenganga at Muzafirabad, the whole of Hazára, and of the hills around Murree (Mari) being included in the Punjab hill ranges. The circumstance that the valley of the Jhelum, which is also the boundary of Kashmir in this direction, closely corresponds with the important change in the main direction of the ranges from the east-north-east strike prevalent in Hazára

[1] No names are applied to these ranges on the map, and almost every writer employs different terms for them. The ranges in the Punjab are not named by the inhabitants of the country, and such distinctive terms as are commonly used appear to be derived either from the tribes inhabiting the hills, as Waziri, Afridi, &c., from the passes through them, from the country around, or from some local peculiarity, as in the case of the Salt Range.

The following are the names used by various writers for the hills forming the western extension of the Salt Range beyond the Indus. The portion near the river, much curved, but having on the whole an east and west strike for some distance, and then turning southwards and running north and south, is known as the Chicháli, Shingarh or Lowagarh and Surgarh. By one writer these hills are called Kháttak. South of the break made by the Kurram river, there is a double range, the northern or north-western, running north-east and south-west, known as the Batani or Shekh Budín ridge, whilst the parallel ridge to the south-east near the bank of the Indus is variously known as Khasor, Betot, Káfirkot, or Rotta Roh. From west of the peak of Shekh Budín another ridge runs to the north-west and joins the Shekh Budín range to the Sulemán. This minor ridge is known as the Pyzu (Peyzoo) from a pass through it. Most of the ridges named consist of tertiary rocks, but older formations occur in the Chicháli or Shingarh and Káfirkot ranges, and under Shekh Budín peak.

to the north-western direction of the Pir Panjál, justifies the selection of this line for the eastern limit of the Himalayan region.

The plains of the Punjab, so far as they require geological notice, or perhaps, it should rather be said, so far as their geology is known, have already been described in the seventeenth chapter with the rest of the post-tertiary Indo-Gangetic plain. The orographical features of the hills to the north and west of the province are peculiar, but our knowledge of the geology requires many additions to be made to it before these features can be understood. The change in the direction of the ranges, caused by a similar alteration in the strike of the rocks at the Jhelum valley, has just been noticed, but this is only one of several similar abrupt changes in the Punjab hills. Commencing again on the frontier of Sind, the Mari and Bhúgti hills, north of Jacobabad, run nearly east and west, whilst the Sulemán Range, from the Sind frontier to Dera Ismail Khan, runs nearly north and south, like the Khirthar and other mountain chains in Sind. The various ranges of the Northern Punjab are so much curved and twisted, that no general direction can be detected; there is, however, in many parts of them, as in the Eastern Salt Range, and in the Shekh Budín hills, a tendency to parellelism with the east-north-east direction of the Hazára hills. The extraordinary curve of the Salt Range at the Indus may be considered a remarkable instance of folding due to compression, but the cause of so singular a change of direction requires further explanation. In the Punjab hills three distinct lines of strike may be traced: that of the Sulemán Range, running nearly north and south; that of the lower Hazára hills, running east-north-east to west-south-west; and that of the Pir Panjál, running nearly north-west and south-east; but all these chains are, in great part at least, of post-pliocene date, for all comprise pliocene beds, and it is difficult to see any reason for doubting that all are of contemporaneous origin.

Geological data.— Our present knowledge of the various hill ranges varies greatly in accuracy and detail. The Salt Range and the elevated tract to the northward in the Ráwalpindi district, known as the Potwár, together with some of the hills west of the Indus forming the trans-Indus salt region, and extending to the neighbourhood of Kohát and Bannu, have been examined and mapped by the Geological Survey[1]; portions of Hazára and the Murree hills have also been surveyed, but of the remainder of the region very little is known. Of the hills of the Deraját from Bannu southward scarcely any information exists. Some notes on the ranges near the Indus, from Kálabágh to Shekh

[1] Chiefly by Mr. Wynne; portions of the Salt Range, of the Murree hills, and Hazára having also been examined by Dr. Waagen. The Salt Range is described at length by Mr. Wynne: Mem. G. S. I., vol. XIV; an account of Mount Tilla having previously

Budín, have been published by Dr. Fleming.[1] A few observations on the geology of the Shekh Budín hills and neighbouring ranges have also been published by Dr. Costello [2] and Dr. Verchere,[3] but the details in all these cases are extremely meagre and imperfect. The Sulemán Range beyond the British frontier has been traversed west of Dera Gházi Khan by Mr. Ball,[4] and some notes on the Mari and Bhúgti hills to the southward were published many years since by Captain Vicary [5]; whilst the only information on the northern part of the range is comprised in some brief notes by Dr. Fleming[6] and Dr. Stewart.[7]

General geological features.—So far as is at present known, the Mari and Bhúgti hills and the Sulemán Range are principally, like the Khirthar and other hills of Sind, composed of tertiary beds, amongst which nummulitic limestone and the conglomerates, sandstones and clays of the upper tertiaries (Manchhar or Siwalik) are the most conspicuous rocks. In the northern part of the Sulemán hills, however, older formations appear, some of them metamorphic. The Shekh Budín and Chicháli or Shingarh hills, west of the Indus, are a continuation of the Salt Range, and contain to a great extent the same rocks, but, as already remarked, they are very imperfectly known. In the Salt Range there is a remarkable series of formations, from older palæozoic to later tertiary, many of them fossiliferous, the oldest rocks being found along the southern base of the range, and all the beds, despite much irregular disturbance, having a general northerly dip. Here the contrast

been published: Rec. G. S. I., III, p. 81. The various descriptions by previous observers are noted in Mr. Wynne's memoir: of these the most important were the reports by Dr. Fleming: J. A. S. B., XVII, 1848, Pt. 2, p. 500, and XXII, 1853, pp. 229, 333, 444. The trans-Indus salt region was described: Mem. G. S. I., XI, pp. (105)—(330); the Kharian hills, south of the Jhelum, Rec. G. S. I., VIII, p. 46; the neighbourhood of Mari (Murree) hill station, Rec. G. S. I., VII, p. 64; and the tertiary rocks of the upper Punjab, Rec. G. S. I., X, p. 107,—all by Mr. Wynne. Some details were also given: Q. J. G. S., 1874, p. 61; 1878, p. 347; and Rec. G. S. I., III, p. 73; VI, p. 59. The geology of Mount Sirban, close to Abbottabad in Hazára, was described by Dr. Waagen and Mr. Wynne: Mem. G. S. I., IX, pp. (331)—(350); whilst Dr. Waagen separately gave an account of a section near Murree: Rec. G. S. I., V, p. 15; and of forms of *Ammonites, Ceratites,* and *Goniatites* from carboniferous rocks: Mem. G. S. I., p. (351). The fossil collections made by Dr. Fleming and Mr. Purdon in the Salt Range were described by Mr. Davidson: Q. J. G. S., 1862, p. 25; and Prof. de Koninck: Q. J. G. S., 1863, p. 1. The only other important contribution to the geology of the Punjab is by Dr. Verchere: J. A. S. B., XXXV, Pt. 2, pp. 89, 159; XXXVI, Pt. 2, pp. 9, &c.

The present and the following chapter are chiefly compiled from data furnished by Mr. Wynne's papers, except where the contrary is stated.

[1] J. A. S. B., XXII, 1853, pp. 259, 261, 268, &c.

[2] J. A. S. B., XXXIII, p. 378.

[3] J. A. S. B., XXXIV, Pt. 2, p. 42; and map, J. A. S. B., XXXVI, Pt. 2.

[4] Rec. G. S. I., VII, p. 145.

[5] Q. J. G. S., 1846, p. 260; Geol. Papers on Western India, p. 521.

[6] Q. J. G. S., 1853, p. 346.

[7] J. A. S. B., XXIX, p. 314.

so frequently noticed between the peninsular and extra-peninsular areas of India is very strongly marked; although the Korána hills,[1] apparently composed of the Arvali transition beds, are but 40 miles distant to the south-east, not a single formation, out of the ten pre-tertiary groups distinguished by Mr. Wynne amongst the rocks of the range, has hitherto been clearly identified with any formation in the peninsular area, and the Salt Range tertiary beds are only represented, as already noticed, in Western India. At the same time the peninsular formations contrast much more strongly with the marine palæozoic and mesozoic strata of the Western Salt Range than with the unfossiliferous sandstones in the eastern part of the hills, and there is not only a gradual passage in the range itself from west to east, from a distinctly marine facies to one more nearly resembling that of the Vindhyan and Gondwána series of the peninsula, but there is still a possibility that some of the peninsular formations may be identified with those of the Eastern Salt Range. All that can be said is that no such identification has hitherto been made. Dr. Waagen suggests[2] that the Salt Range marks the passage from the extra-peninsular to the peninsular type of rocks, and these hills may consequently be on the margin of the ancient land area, of which the Indian Peninsula formed a portion in palæozoic and mesozoic times.

Rock-groups of Salt Range.—The following is a general list of the rock-groups found in the Salt Range in descending order[3]:—

	European equivalents.	*Name.*	*Character of rocks.*	*Approximate thickness, in feet.*
TERTIARY.	PLIOCENE	14 Upper Siwalik	Conglomerates, drab and pink clays	300 to 2,000
	MIOCENE (?)	13 Lower Siwalik[4]	Grey sandstones and red clays, with mammalian bones	1,200 to 7,500
		12 Náhan ?	Greenish-grey sandstones	600 to 1,000
	EOCENE	11 Nummulitic	Pale limestones, with nummulites and other fossils	400 to 600
			White sandstones, shales, and red and grey clays, with lignite and gypsum	150 to 300

[1] *Ante*, p. 52.

[2] Denkschr. K. Akad. Wiss. Wien., 1878, p. 8.

[3] Wynne, Mem. G. S. I., p. 69. The Salt Range was mapped geologically by Mr. Wynne, but Dr. Waagen spent part of a season in examining the rocks and added to the accurate determination of the fossiliferous formations, besides distinguishing the triassic group, which had previously only been separated on lithological characters. Unfortunately, his health having failed, Dr. Waagen was obliged to leave India without working out the palæontology. He is now occupied in determining the fossils.

[4] As will be shewn subsequently, it is possible Nos. 12 and 13 of the list, the "lower Siwalik" and "Náhan" of Mr. Wynne's classification, should rather be classed as middle Siwalik (pliocene). See foot-note, p. 512.

	European equivalents.	*Name.*	*Character of rocks.*	*Approximate thickness, in feet.*
MESOZOIC.	CRETACEOUS	10. Olive group	Olive, reddish brown and white sandstones, slightly calcareous beds, shales and black clays with boulders, slightly fossiliferous	150 to 350
	JURASSIC	9. Variegated group	Red, white and variegated sandstones, yellow and grey limestones and marls, fossiliferous	200 to 500
	TRIASSIC	8. Pseudomorphic salt crystal group.	Red and pale-coloured flaggy sandstones with blood-red clays or shales, unfossiliferous	50 to 500
		7. Ceratite beds	Grey limestones, calcareous sandstones, and grey marls, weathering greenish, fossiliferous	120 to 250
AZOIC AND PALÆOZOIC.	CARBONIFEROUS	6. Carboniferous limestone.	Grey and pale magnesian limestone, calcareous sandstone, and argillaceous beds, highly fossiliferous	300 to 500
	?	5. Speckled sandstones	Speckled, reddish and white sandstone, and lavender clay, unfossiliferous	250 to 450
	?	4. Magnesian sandstone	Light-coloured magnesian sandstone and shales, unfossiliferous	50 to 250
	SILURIAN ?	3. *Obolus ?* beds	Black shales with glauconitic calcareous layers and sandy bands, fossiliferous	30 to 150
	?	2. Purple sandstones	Deep purple sandstones, unfossiliferous	250 to 450
	?	1. Salt marl	Red gypseous marls with thick beds of rock salt and thin dolomitic layers	800 to 1,500 base not seen.

Scarcely any of these groups, except the salt marl at the base, and the later tertiary beds at the top of the series, are found throughout the range, although the nummulitic limestone is only absent in a few localities at each end. No. 2 of the preceding section, the purple sandstone; No. 3, the black silurian shales; No. 4, the magnesian sandstone; No. 8, the red sandstones and shales, with pseudomorphs of salt crystals; and No. 10, the olive group, are all wanting in the western part of the range: whilst No. 5, the speckled sandstone; No. 6, the carboniferous limestone; No. 7, the triassic limestone; and No. 9, the jurassic group, are absent to the eastward. Similar differences may exist between the Western Salt Range and the continuation west of the Indus; one formation, the neocomian, is certainly found to the westward, but not east of the river. The important distinction, however, is the prevalence of marine fossiliferous rocks in the western, and of unfossiliferous beds in

the eastern part of the range, all the principal fossiliferous formations below the olive series, the carboniferous, triassic and jurassic beds, being restricted to the western portion of the area.

Rock-groups of Hazara, and the Northern Punjab.—The rocks to the northward in Hazára and near Murree, and in the hills of the Northern Punjab near Attock and Pesháwar, differ to a very great extent from the Salt Range beds. Although the formations are, in many cases, of similar age, marine eocene, cretaceous, jurassic and triassic rocks being found in both areas, there is a marked distinction, both in mineral character and in fossils, between the mesozoic rocks in Hazára and those in the Salt Range, and no connexion has been traced between any of the palæozoic groups. The nummulitic limestone also exhibits differences in the two regions. The mesozoic rocks of the Northern Punjab are more closely connected, both by mineral character and fossils, with the comparatively distant trans-Himalayan beds of Zanskár, Rupshú and Spiti, than with the strata of the Salt Range.

The following are the formations found in the extreme north of the Punjab:—

	European equivalents.	*Name.*	*Character of rocks.*	*Approximate thickness, in feet.*
TERTIARY.	EOCENE	Nummulitic	Limestone, chiefly dark-coloured, and shales; some carbonaceous shales locally near the base	1,700 to 3,000
MESOZOIC.	CRETACEOUS	———	Thin-bedded limestones, unfossiliferous	60 and upwards ? 300
			Sandy and rusty limestones, fossiliferous	20
	JURASSIC	Gieumal beds, Spiti shales, &c.	Sandstones, &c., poorly fossiliferous	30
			Limestones, fossiliferous	10 to 100
			Black shales, sandy beds, &c., fossiliferous	30
	TRIASSIC	———	Limestones, magnesian in part, shales and sandstones, fossiliferous	2,000 or less
AZOIC AND PALÆOZOIC.	INFRA-TRIASSIC	———	Siliceous and dolomitic breccia, shales, sandstones, unfossiliferous.	
	TANOL (TANÁWAL) GROUP	———	Quartzites, conglomerates, slates, schists and magnesian limestones, unfossiliferous.	
	SILURIAN ?	Attock slates	Black and grey slates, limestones, &c.	
	?	Schistose beds, quartzites and dolomites.		
	?	Metamorphic and crystalline rocks.		

Abnormal boundary of upper tertiaries.—The boundary between the palæozoic and mesozoic beds, with the hill nummulitic limestone

on the one hand, and the upper tertiaries, including the beds classed as upper nummulitic, on the other, is very marked, and has the appearance of a great crushed fault[1]; it is not clear, however, whether the break is entirely due to faulting, or whether it may not in part be the result of unconformable deposition subsequently to the consolidation of the hill area. One of the chief peculiarities of this boundary is the apparent inversion of the rocks, the newer beds to the south of the junction having commonly a dip towards the north, as if they were inferior in position to the older formations to the northward. The line of fracture is not always simple; occasionally it bifurcates or consists of two or more parallel lines, nor is it an absolute boundary between the two types of tertiary rocks, for the hill variety of the nummulitic limestone is occasionally brought up by faults or exposed in crushed anticlinals to the south of the main line of division, and the newer tertiary beds are similarly met with in places faulted or let in by synclinals to the north of the boundary. The most remarkable occurrence of the hill nummulitic limestone south of the dividing line is in the ridge of Khairi Múrat, south-west of Ráwalpindi, and 10 miles south of the main limit of the formation; whilst the newer tertiary beds are found represented in the Mir Kúlan pass, west of Attock, nearly as far to the north of the junction line, and at Dungagalli, north of Murree hill station. It should, however, be mentioned that the outliers of newer tertiary beds within the area of the hill rocks are not quite so clearly identified as the outlier of nummulitic limestone exposed south of the dividing line.

This discordant junction between the Himalayan rocks and the tertiary formations is not confined to the North-Western Punjab, but is traced throughout the ranges to the east of the Jhelum in Kashmir territory, and thence far to the south-east along the southern slope of the Himalayas. There is, however, this distinction between the boundary in the Northern Punjab and that farther to the south-east, that the eocene formations are found superbly developed as the hill type of nummulitic limestone north of the junction line in the Northern Punjab; whereas to the eastward the rocks on the northern side of the boundary appear, except in the Sirmúr area of the Simla region, to be much older than tertiary. In the Punjab, too, at no great distance to the south of the line, fossiliferous beds of similar age to those found in the Himalayan area are exposed, although the fossil fauna is in some cases different, whilst no similar connection has been traced between the Himalayan rocks and those of the Peninsula generally, except in the

[1] Wynne, Q. J. G. S., 1874, p. 69.

solitary instance of the Damúda beds in Sikhim. One more peculiarity of the abnormal boundary in the Northern Punjab is that the direction here is far more irregular than it is farther to the south-east, and that the boundary line leaves the slopes of the Himalayas to which it is confined to the eastward, and traverses the upper Punjab from east to west.

Commencing at the western end, the abnormal line of junction just described runs along the south of the Afridi hills, and of the Chitapahár and Márgalla ranges north of the Ráwalpindi plain to the Murree hills. So far the direction has been that of the ranges, nearly from west to east, curving to north-east to the eastward. Near the Jhelum, however, the line turns sharply north and runs up the valley of the river to Muzafirabad, whence the boundary turns again sharply to the south-east along the flanks of the Kaijnág range in Kashmir.

A similar abrupt boundary between the older hill rocks and the upper tertiary formations is found along the northern side of the Alps in Europe; and amongst some of the mesozoic rocks there is a singular replacement in the mountain zone, both in the Alps and Himalayas, of formations, occurring in the plains at no great distance, by beds of corresponding age, but differing both in mineral character and fossil fauna. This distinction is most marked in the case of the jurassic rocks,[1] but there is a similar difference in the Trias of the Himalayan and extra-Himalayan regions. The palæozoic beds of the Himalayan Northern Punjab differ also from those of the Salt Range, but the distinction is of a different character, and probably local, for the carboniferous limestone, the only important fossiliferous palæozoic group of the Salt Range, reappears in Kashmir, and the fauna is similar to that of the mountain limestone so widely distributed throughout Europe, Asia, Australia, &c.

Azoic and palæozoic rocks of Salt Range, &c.—Under the circumstances of the case, it appears best to describe separately the palæozoic and mesozoic rocks of the two contrasting areas, and to commence with the southern region. As the rocks of the Salt Range alone are well known, the description of the older non-Himalayan Punjab formations must be almost confined to the area between the Indus and Jhelum, the occurrence of similar beds west of the Indus being noticed wherever their existence has been ascertained.

[1] Waagen, Pal. Ind., Ser. IX, p. 236; Waagen and Wynne, Mem. G. S. I., IX, p. (332); see also Wynne, Mem. G. S. I., XIV, p. 64; and Waagen, Denkschrift M. N. Kl. K. Akad. Wien, XXXVIII, 1878, p. 12.

In the ranges west of the Indus, the greater part of the area is occupied by tertiary rocks, palæozoic beds occurring, however, in the Chicháli range, and forming a considerable portion of the Káfirkot hills. In the southern part of the Sulemán ranges no pre-tertiary formations have hitherto been noticed, but the occurrence of carboniferous limestone west of Dera Ghází Khan has been inferred from the existence of fragments in the beds of streams running from the range. Farther north, in the Mahsud Waziri country, south-west of Bannu, the higher ranges consist of metamorphic and schistose rocks.[1]

Salt marl.—At the base of all the Salt Range sections, throughout the range from east to west, there is found a great thickness of red marl, varying in colour from bright scarlet to dull purple, and containing thick bands of rock salt and gypsum and a few layers of dolomite. The base of this group is nowhere seen, so that the thickness is unknown; all that can be ascertained is that it is not less than 1,500 feet.

The marl itself, which consists of clay, having carbonate of lime and magnesia and a small proportion of sulphate of lime (gypsum) combined, is soft and homogeneous, and the only evidence of stratification, as a rule, is to be found in the intercalated beds of salt, gypsum, and dolomite. In these the strata are frequently seen to be much broken and contorted, although no evidence of disturbance can be seen in the marl itself. Besides the more regular beds, masses of gypsum are frequently irregularly dispersed throughout the marl. Many crystals of quartz and a few of iron pyrites have been found locally in the gypsum. In one locality in the Khewra gorge near Pind Dadun Khan a small quantity of bituminous shale was discovered.

The beds of rock salt to which the group owes its name are very rich, some separate bands being as much as 100 feet in thickness, and there being frequently several thick beds at one locality. Thus at the Mayo Mines of Khewra there are altogether no less than 550 feet of pure and impure salt in the upper 1,000 feet of the salt marl: of this thickness, 275 feet, or one-half, consists of nearly pure salt; the other half, known as *kalar*, being too earthy and impure to be of marketable value without refining. The salt of the Punjab, it should be noted, is transported and sold in the market as it is dug from the mine, without being refined. The beds of salt, so far as they are known, are most abundant in the upper portion of the group, and the principal bands of gypsum overlie the salt beds. The salt bands do not appear to be continuous

[1] Stewart, J. A. S. B., XXIX, 1860, p. 316; Verchere, J. A. S. B., XXXVI, 1867, Pt. 2, p. 18.

over a large area, but owing to the manner in which the outcrops are usually dissolved by rain, and then covered up by the marl, it is impossible to trace the beds. The salt itself is white, grey or reddish, and is frequently composed of alternating white and reddish layers, differing in translucency as well as in colour. Some bands are almost pure, others contain small quantities of sulphate of lime and chlorides of calcium and magnesium. At the Mayo Mines one band has been found, 6 feet thick, composed of a mixture of sylvine (chloride of potassium) and kieserite (sulphate of magnesia, with only one equivalent of water), and the latter salt prevails throughout about 7 feet beneath the sylvine band. Epsom salts (sulphate of magnesia, with seven equivalents of water) are produced when water from the atmosphere is absorbed by the kieserite, and they frequently weather out on the surface, shewing that the magnesian salt is of common occurrence in the rock. Glauberite (anhydrous sulphate of soda and lime) has also been found by Dr. Warth, to whom the discovery of most of the salts mentioned is due.

Owing to the softness of the marl, and to the tendency of harder rocks to slip upon it whenever it is sufficiently saturated with water to destroy its coherence, and also to the salt beds being dissolved by water, the rocks of the Salt Range are broken and mixed up in the most complicated manner, masses of the marl having been squeezed by pressure in places into a position in which they appear to overlie more recent rocks, whilst all the newer formations are cracked and faulted. The detailed geology of the range is consequently very intricate, and it is not always easy to tell whether dislocations of the strata are due to true faults traversing all the beds, inclusive of the salt marl, or whether the displacement is merely due to complicated landslips.

Besides being found from end to end of the Salt Range along the base of the southern scarps, the salt marl is exposed for a short distance beyond (west of) the Indus in the hills behind Kálabágh. The same rock is said by Dr. Verchere (and shewn upon his map) to be found at the northern and southern extremities of the Káfirkot hills (Rotta Roh of Verchere), west of the Indus, and south of Isa Khel, and round the southern base of the Shekh Budín peak, a few miles farther west. Dr. Fleming also [1] mentions the occurrence of red and grey saliferous sandstones under carboniferous limestone at the northern extremity of the Káfirkot range. The salt of the Kohát district is derived from beds of apparently much later date than those of the Salt Range.

In a few places, a volcanic rock, having the appearance of diorite, but much decomposed, is found in the upper portion of the salt marl

[1] J. A. S. B., XXII, 1853, p. 260.

just below the purple sandstone. It occurs in horizontal lenticular layers from a few inches to 6 feet or more in thickness, and contains, in abundance, acicular stellate crystals, much decomposed, but apparently of hornblend (tremolite or actinolite), together with talc, quartz, and calcite; the latter in small cavities. It is not at all certain whether this igneous rock is intrusive or contemporaneous, but its occurrence in lenticular beds is in favour of the latter view.

There can be no reasonable doubt that the salt marl is a sedimentary rock, although its very peculiar appearance has induced some observers to suspect an igneous origin. The red colour, however, due to the occurrence of iron sesquioxide, is a normal character of beds containing salt. The absence of organic remains is also a common peculiarity of saliferóus rocks. Whether such formations with their beds of rock salt and gypsum have been deposited in salt lakes under process of desiccation, does not appear to be equally generally admitted.[1] The amount of salt in the beds of the Salt Range is so great, that successive supplies of salt water and repeated evaporation alone could produce the thickness of the mineral found in places.

The geological age of the salt marl and of the next formation in ascending order, owing to the absence of fossils, is somewhat doubtful, but the presence of a bed, probably of silurian age, at a higher horizon, shews that both must be of very ancient palæozoic date.

2. Purple sandstone.— The group next above the salt marl consists almost entirely of sandstone of a dull purple colour, containing carbonates of both lime and magnesia. The lower fifty to a hundred feet are more argillaceous, and perhaps indicate transition from the marl below; in the higher portion of the group bands of clay are rare or absent. Near the top the colour becomes paler.

This purple band is found throughout the eastern part of the range, but it dies out to the westward, or is replaced by an argillaceous conglomerate. No fossils have been found in the present group, which has not hitherto been traced beyond the Salt Range.

3. Silurian (?).—Throughout the eastern portion of the range some blackish sandy shales, of a dull purple colour when dry, overlie the purple sandstones, and although comparatively of small thickness, are well seen in various cliff sections. Sandy or conglomeratic and calcareous bands occur in the group, but the shaly character is predominant. In these shales a species of Brachiopod belonging to the genus *Obolus*, or some allied form, has been found. *Obolus* is a characteristically lower

[1] For a discussion of this question, and references, see Wynne, Mem. G. S. I., XI, p. (141), and XIV, p. 82.

silurian type, but the determination is not sufficiently certain to fix the age of the shale definitely.

4. Magnesian sandstone.—The next group in ascending order is also confined to the eastern portion of the Salt Range, and consists, in its typical form, of a calcareous sandstone, containing magnesia, or of a sandy dolomite, (the latter being perhaps the more correct term,) a hard, massive cream-coloured rock, conspicuous on the scarps from its massive character. Associated with the harder beds are light-coloured sandstones, occasionally with oolitic layers or flaggy bands, intercalated with greenish and dark-coloured shales.

To the westward this group becomes chiefly composed of sandstones and shales, and is no longer characteristic. No fossils have been found in these beds.

5. Speckled sandstone.—In the Eastern Salt Range the dolomitic beds just noticed are succeeded in ascending order by a bright red argillaceous band, No. 8, and then by the olive beds, No. 10; but to the westward other zones are found to intervene, by far the most important of which is the carboniferous limestone. Beneath this, however, and overlying the magnesian sandstone, there is a group of beds consisting chiefly of light-coloured sandstones, with reddish or purplish specks and patches. With the sandstones, red clays and shales, and some very distinctly marked lavender and purplish or greyish argillaceous and gypseous bands, are intercalated, especially in the higher part and at the top of the group. Some traces of copper in the form of small nodules of copper glance have been discovered in these shales, but these concretions are of rare occurrence. The sandstones are commonly distinguished by the occurrence of small concretionary nodules which project in the form of small knobs from the weathered surface. These beds are in parts conglomeratic, containing pebbles of crystalline rocks, and this conglomeratic character increases to the westward. The speckled sandstone group, although well developed throughout the western part of the Salt Range, is lost near the Indus.

Carboniferous.—With the exception of the few *Brachiopoda* from the supposed silurian shales, the oldest fossils hitherto found in the Salt Range occur in the carboniferous rocks, from which a very rich and characteristic fauna has been obtained. The most prominent beds are grey and yellowish limestones, frequently magnesian, and closely resembling the mountain limestone of the British Isles and other parts of Western Europe in texture, colour, and composition, as well as in organic remains. At the base of the group, shales often predominate, succeeded by reddish and yellowish sandstones with *Spirifer*, remains of fish, &c., the sandstones sometimes containing thick beds of black coaly and sandy

shale. The upper part of these sandstones is fossiliferous,[1] and they are succeeded by limestones with numerous *Cephalopoda, Brachiopoda, Bryozoa, Crinoidea*, &c. The upper strata are again sandy, and sometimes consist of light-coloured sandstones with coaly shales and argillaceous beds intercalated, one thick sandstone bed being crowded with a species of *Bellerophon.* The sections vary in different places; beds of sandstone may occur anywhere, and very frequently the massive grey limestone is found at the base of the group resting upon the uppermost lavender clays of the speckled sandstone group.

The carboniferous formation is wanting in the eastern part of the Salt Range,[2] and appears first in the Nilawán ravine near Kallar Kahár, in the form of coarse, light-coloured yellowish-grey and greenish sandstones with coaly laminæ and a band of sandy calcareous shales. The sandstones contain *Productus spinosus*, and the whole group is but 60 to 70 feet thick, resting on the lavender clays of the underlying subdivision. To the westward the carboniferous beds gradually expand to a thickness of 450 or 500 feet, forming in many places a steep scarp, and maintaining this thickness to the neighbourhood of the Indus. Here, like most of the other rocks, they disappear for a space, but they reappear, according to Fleming, in the Chichâli hills, about 7 miles north of Kálabágh, and may thence be traced along the range to near Mulakhel, a distance of about 25 miles. At this spot they are covered up by newer

[1] The following carboniferous fossils, chiefly *Brachiopoda*, are figured on Plate I; the greater portion are from the Salt Range, several being found also in Kashmir and other Himalayan tracts, and a few being peculiar to the latter:—

Figure 1.	*Spirifer keilhavii.*	*Figure 8.*	*Productus semireticulatus.*
„ *2.*	*S. moosakhailensis* ½.	„ *9.*	*P. costatus* ½.
„ *3.*	*Spiriferina octoplicata.*	„ *10.*	*P. purdoni.*
„ *4.*	*Athyris subtilita.*	„ *11.*	*Strophalosia morrisiana.*
„ *5.*	*Retzia radialis.*	„ *12.*	*Chonetes hardrensis, var. thibetanus.*
„ *6.*	*Camerophoria purdoni.*		
„ *7.*	*Streptorhynchus crenistria.*	„ *13.*	*Aviculopecten hyemalis.*

[2] According to Dr. Waagen, the carboniferous rocks of the Western Salt Range are represented by unfossiliferous sandstones associated with the magnesian limestone to the eastward. He says (Denkschrift Math. Naturwiss. Class. Kais. Acad. Wiss. Wien, 1878 XXXVIII, p. 8), writing of the palæozoic rocks of the Salt Range generally:—" It is very difficult to trace the separate bands through the various phases of their transformation from west to east, but I have endeavoured to do this at least for the lowest strata of the so-called carboniferous limestone, and have found that this formation, proceeding from west to east, passes, first, into a coarse-grained white sandstone which still contains a very few fossils consisting of rolled fragments of coral; next, into a very coarse conglomerate, with boulders the size of a man's head or larger; and lastly, into a homogeneous greyish-green sandstone without any organic remains, which again appears to be closely connected with Wynne's magnesian sandstone."

rocks, but they are again found well-developed in the Káfirkot range, south of Isa Khel (Esakhel). Carboniferous rocks do not appear to have been recognised under Shekh Budín, but they occur to the north-west in the country beyond the British frontier,[1] as fragments of black limestone with *Productus* are found in the river Kurram, draining the southern slopes of the Sufed Koh; and Dr. Fleming found boulders of *Productus* limestone in the streams running from the Sulemán Range as far south as the neighbourhood of Dera Gházi Khan.[2]

The following is a list of the fossils hitherto discovered in the carboniferous limestone of the Salt Range and the neighbouring hills, as determined by Messrs. Davidson[3] and de Koninck,[4] some species considered by those authors as probably from higher horizons having been omitted, as it has been shewn that fossils from triassic, and even from higher beds, had been mixed with carboniferous. Three *Cephalopoda* described by Dr. Waagen[5] have also been added. Species marked *e* are also found in Europe or America.

PISCES.

Saurichthys ? indicus.	*Acrodus flemingianus.*

Acrodus, sp. nov.

CEPHALOPODA.

Orthoceras decrescens.	*Goniatites primas.*
O. rachidium.	*Ceratites carbonarius.*
O. vesiculosum.	*C.* sp. indet.
Nautilus flemingianus.	*Ammonites* (*Phylloceras*) *oldhami.*

GASTEROPODA.

Macrocheilus avellanoides.	*Bellerophon orientalis.*
M. depilis.	*B. decipiens.*
Bellerophon jonesianus.	*Dentalium herculeum.*

LAMELLIBRANCHIATA.

Solenopsis imbricata.	*Pecten asiaticus.*
Pecten crebristria.	*P. flemingianus.*

Anomia lawrenciana.

[1] Verchere, J. A. S. B., XXVI, Pt. 2, p. 21.

[2] Q. J. G. S., 1853, p. 348. The boulders of palæozoic limestone found by Vicary Q. J. G. S., 1850, p. 45, in the streams near Peshâwar are also said by Verchere to have contained carboniferous fossils. See foot-note, p. 500

[3] Q. J. G. S., 1862, p. 25.

[4] *Ib.*, 1863, p. 1.

[5] Mem. G. S. I., IX, p. (351.)

BRACHIOPODA.

Terebratula himalayensis.
T. subvesicularis.
e *Athyris royssi.*
e *A. subtilita*, var. *grandis*, Pl. I, fig. 4.
e *Retzia radialis*, var. *grandicosta*, fig. 5.
e *Spirifera striata.*
S. moosakhailensis, Pl. I, fig. 2.
e *S. lineata.*
e *Spiriferina octoplicata*, Pl. I, fig. 3.
e *Rhynconella pleurodon.*
Camerophoria purdoni, Pl. I, fig. 6.
e *Streptorhynchus crenistria*, Pl. I, fig 6.
e *Streptorhynchus* do. var. *robustus.*
S. pectiniformis.
e *Orthis resupinata.*
e *Productus striatus.*
e *P. longispinus.*
e *P. cora.*
e *P. semireticulatus*, Pl. I, fig. 8.
e *P. costatus*, Pl. I, fig. 9.
e *P. purdoni*, Pl. I, fig. 10.
P. humboldtii.
e *Strophalosia morrisiana*, fig. 11.
Aulosteges dalhousii.
Crania, sp.

BRYOZOA.

Phyllopora ? cribellum.
P ? haimeana.
Retepora ? lepida.
Fenestella ? sykesi.
F. megastoma.
Polypora fastuosa.

ECHINODERMATA.

Philocrinus cometa.
Poteriocrinus ? sp.

ANTHOZOA.

e *Alveolites septosa ?*
e *Michelinia favosa.*
e *Lithostrotion irregulare.*
e *L. basaltiforme.*
Clisiophyllum indicum.

It has been shewn by Dr. Waagen that *Dentalium herculeum* and *Bellerophon jonesianus* occur at a higher horizon than the other fossils and immediately beneath triassic beds with *Ceratites*, &c. *Strophalosia morrisiana* is a Permian form in Europe, and the *Aulosteges* has Permian affinities rather than carboniferous, but most of the *Brachiopoda* and many of the other fossils are characteristically carboniferous. The occurrence, therefore, of a true ammonite and a ceratite, two forms of *Ammonitidæ* not previously found in palæozoic beds, is very remarkable. It was certainly believed by Dr. Fleming that he had found *Ceratites* together with the carboniferous *Brachiopoda*, but the species of the former genus described from his collections are found in a higher bed, which is really of triassic age. The ammonite and the two ceratites discovered by Dr. Waagen, however, were procured by himself, together with *Goniatites primas*, in the upper portion of the group, from a bed containing several typically carboniferous *Brachiopoda*, including *Athyris royssi*, *A. subtilita*, *Spiriferina octoplicata*, *Streptorhynchus crenistria*, *Productus costatus*, &c.

The triassic beds appear not only to be perfectly conformable to the carboniferous of the Salt Range, but to pass into them, and Dr. Waagen

has suggested that some of the upper carboniferous rocks are really of Permian age.

Mesozoic rocks of Salt Range, &c.,—Ceratite beds.—Immediately above the carboniferous limestone, and so closely connected with it as not to have been distinguished except lithologically until the rocks were examined by Dr. Waagen, there is found in the Salt Range, and probably in some of the hills west of the Indus also, a group of marls, limestones, and sandstones, containing a distinctly triassic fauna. The lowest beds of this group are generally thin limestones with *Ceratites*, succeeded by a conspicuous thick marly zone, weathering of a light greenish colour. This is overlaid by grey sandstone and flaggy limestone layers, passing upwards into hard nodular marls, and a succession of similar beds forms the upper portion of the group. Some of the bands of limestone contain glauconite, and beds of conglomerate occasionally occur. In places the formation is chiefly composed of shales and marls.

Like the carboniferous, the triassic group is only found in the western part of the Salt Range, the eastern limit of the latter being some miles farther west than that of the older formation. Triassic beds are found associated with the carboniferous group from the spot where they first appear south-west of Naoshera to the neighbourhood of the Indus. Of their range west of the Indus very little is known; they certainly occur in the range near Káfirkot, as this is one of the localities whence *Ceratites buchianus* was originally procured,[1] and other species of the same genus were found in the same range by Verchere,[2] but it is not so certain whether the trias is represented in the Chicháli range. Dr. Fleming, however, especially states[3] that the upper limestone of the carboniferous group is more distinct in the Chicháli hills than it is west of the Indus, and the beds now known to be of triassic age were included by Dr. Fleming in the upper portion of the carboniferous.

Owing to the triassic beds of the Punjab having been at first confounded with the underlying carboniferous rocks, the fossils of the former have not been sufficiently distinguished for any list to be given.[4] Ceratites abound, and most of the species, probably all, described by de Koninck—*C. flemingianus*, *C. murchisonianus*, *C. haueriannus*, *C. planulatus*, *C. lyellianus*, *C. latifimbriatus*, *C. buchianus*, *C. davidsonianus* and *C. lawrencianus*—are from the triassic rocks. Besides the *Ceratites*, which are the characteristic fossils of the formation, species of *Orthoceras*, *Anoplophora*,

[1] Q. J. G. S, 1863, p. 13.

[2] J. A. S. B., XXXVI, 1867, Pt. 2, p. 221.

[3] J. A. S. B., XXII, 1853, p. 264.

[4] As already mentioned in a previous note, those collected by the Geological Survey have been sent to Dr. Waagen for examination.

Cardinia, Gervillia, Rhynconella, &c., occur in large numbers; the bivalves being especially characteristic of the upper beds. The most remarkable fossil, however, is a species of *Bellerophon,* a genus not known to occur in Europe in rocks of later age than palæozoic.

The ceratite beds are probably about the age of the Bunter (lower trias), whilst a *Myophoria* in the overlying limestone closely resembles a Muschelkalk species. Above this no distinct fossil zone can be recognised until the middle jurassic is reached.

Pseudomorphic salt-crystal zone.—A group of thin-bedded and flaggy sandstones, with intensely red shales and clays, is conspicuous in the eastern part of the Salt Range, resting upon the magnesian limestone, and overlaid by the cretaceous olive shales. Where well developed, the upper portion of the present group is argillaceous, the lower portion, which is of less thickness than the upper, being chiefly composed of flags and sandstone, but there is some variation in the section; in places the lower portion of the group consists of red and variegated clays and shales, and where the band is less developed, it consists mainly of flaggy sandstones. On the surface of the sandstones cubical pseudomorphs of salt crystals abound, and are so characteristic that they serve to distinguish the beds. The band is also remarkable for the bright red colour of some of the clays.

The present group is unfossiliferous or nearly so, only some obscure organic traces of doubtful origin having hitherto been detected in it. Its position in the series is far from certain, for it is nowhere in contact with fossiliferous jurassic, triassic, or carboniferous beds; it rests upon the magnesian limestone, and is overlaid by the cretaceous olive group. Each of the three groups, although they appear to form part of a continuous and conformable series, is well distinguished by mineral character and by relations to the other beds; both the overlying and underlying groups being in fact unconformable on the large scale to the intermediate salt-crystal formation, for the speckled sandstone in the western part of its extent intervenes between the place of the salt crystal beds and the magnesian sandstone, whilst the olive group completely overlaps the salt crystal formation, and rests upon older formations to the westward. The reference of the present group to the trias is consequently but little more than a suggestion, and must be considered as liable to alteration, should further evidence be obtained.

The pseudomorph salt-crystal formation is found from Mount Tilla, near the eastern extremity of the Salt Range, to Makrách, north-west of Pind Dadun Khan, but is wanting at Chambal mountain near Jalálpur. West of Makrách no such band is found, nor are similar rocks known west of the Indus.

Jurassic or variegated group.—The next group in ascending order is again a western formation; it consists of soft white and red sandstones, with grey and yellowish limestones and yellow marls, and is unknown in the eastern part of the Salt Range. The lower beds of this jurassic group rest upon the triassic rocks, and consist of sandstones of varying colour, succeeded in ascending order by limestones, clays, and soft white sandstones; then come bands of hæmatite, several feet in thickness, and thinner layers of golden oolite, precisely similar to the rock of Cutch, and the upper portion of the group consists of coarse brown sandstones, yellow marls, white sandstone and hard grey limestone bands. The sandstones are often conglomeratic, and the limestones are most largely developed to the westward. Small layers and patches of bright jetty coal occur in places towards the base of the group, and west of the Indus near Kálabágh these masses are sufficiently abundant to have been worth extraction for the purpose of supplying fuel to the river steamers, but the supply is small; there is nothing like a seam of coal, and no prospect of regular mining operations being successful. The patches of coal appear to be merely carbonized fragments of drift wood.

The Salt Range jurassic beds are not found east of the neighbourhood of Naoshera; they begin to appear a little farther west than the triassic ceratite strata, and increasing much in thickness continue into the Indus. West of that river the same rocks reappear in the Chicháli hills, where they are well developed and more fossiliferous than in the Salt Range; they are well seen in the Chicháli pass, and extend further to the southward round the curve of the range than the carboniferous limestone does, but they disappear beneath the tertiary rocks about 6 miles south of Mulakhel.[1] They are wanting in the northern portion of the Káfirkot range, but are said by Verchere[2] to be well developed at Shekh Budín. On Verchere's map, too, jurassic rocks are represented as occurring in the southern part of the Káfirkot range and also near Bahádur Khel, north-east of Bannu, but Mr. Wynne was unable to find any in the latter locality, although he searched for them in the place indicated. Fleming mentions that *Belemnites* are brought by natives of the country from the Sulemán Range near Dera Gházi Khan, and Verchere found coral limestone, which he considered probably jurassic, in the Waziri country, west of Shekh Budín.[3]

Until the fossils of the Salt Range jurassic beds are examined in detail, it is not possible to say exactly what members of the jurassic

[1] Fleming, J. A. S. B., 1853, p. 278.
[2] J. A. S. B., 1867, p. 15,
[3] l. c., p. 19.

series are represented. Dr. Waagen has shewn that there is a close connexion between the Salt Range oolitic beds and those of Cutch,[1] but that the Himalayan Spiti shales contain a very different fauna. The Kelloway portion of the Chári beds is distinctly represented in the Punjab, and some of the higher jurassic groups also. *Cephalopoda* are scarce, except west of the Indus, where *Ammonites* and *Belemnites* occur rather more abundantly, especially in the fine section of jurassic beds exposed in the Chicháli pass.

Cretaceous (neocomian).—In the Chicháli pass, north-west of Kálabágh on the Indus, the upper jurassic beds, consisting of dark olive clays and sandstones, with patches of oolitic limestone, pass upward into similar beds of a dark blackish-green colour, containing lower neocomian *Cephalopoda*,[2] and these, again, are capped by 60 feet of massive sandstone, light coloured above, black below. This is the only instance in which beds with a lower neocomian fauna have yet been clearly ascertained to occur in India; upper neocomian *Cephalopoda* have, as already stated, been found in Cutch, and some of the *Ammonites* from Sripermatur were also thought by Dr. Waagen[3] to resemble neocomian species.

Olive group.—So far, there is no well-marked break in the series of mesozoic formations, although several groups may be unrepresented, but the next formation in ascending order is much more abruptly limited below. It is found to the eastward, and consists of sandstones of various shades of dark green, grey, olive, and whitish, olive being the prevailing tint. In the upper part some shaly and carbonaceous bands occur, and in the lower part dark shales, filled with large boulders of crystalline rock.[4]

This boulder conglomerate is an extremely interesting formation, for it affords a second instance in India (the Tálchir group being the first example noted) of the characteristic marks of glacial action being found in ancient deposits. Other conglomerates, sometimes containing fragments of rock of large size, are found at a lower horizon in the Salt Range, but the only instance in which evidence has been detected of

[1] Pal. Ind., Ser. IX, p. 236.

[2] Waagen, Pal. Ind., Ser. IX, p. 245.

[3] Denkschr. K. Akad. Wiss. Wien., l. c. p. 12.

[4] In mineral character, in the occurrence of boulders, and in the evidence of glacial conditions at the period of deposit, there is a curious resemblance between this conglomerate of the Salt Range and the Tálchir group of the Gondwána system (see *ante*, p. 109); and Mr. Theobald, the only geologist with any experience of the Tálchir beds who has examined the Salt Range, noticed the similarity (Rec. G. S. I., X, p. 224).

the boulders having been transported by ice is in the olive group. Mr. Theobald found[1] a rounded fragment of red granite, rather less than a foot in diameter, on the surface of this conglomerate, and apparently derived from it; the block is polished and striated on three faces in so characteristic a manner, that very little doubt can exist as to its having been transported by ice. The parent rock of this and many similar fragments found in the same conglomerate is unknown, no crystalline formation is exposed in the neighbourhood of the Salt Range, and no red granite, like that of which the boulders are composed, is known in the Himalayan region to the northward. Some of the transported fragments are much larger than the specimen already mentioned, and at Narwari, a mile east of the Collector's house at the Mayo Salt Mines of Khewra, one block of red granite occurs 7 feet high and 19 in circumference; another large mass lies in the upper part of the Bághanwála ravine in the eastern part of the Salt Range. The derivation of these two blocks from the conglomerate of the olive group is not, however, certain.

The boulder shales at the base of the olive group are found throughout a considerable area in the eastern Salt Range, but they are not coextensive with the overlying sandy beds. In the latter, fossils are occasionally found, having for the most part a tertiary facies, but one species of *Ammonites* has been found.[2] Large *Nautili*, *Echinodermata*, corals, and *Terebratula flemingi* are the principal forms occurring. *Cardita beaumonti* occurs, but it is rare.

The olive group is very closely connected with the tertiary beds; it appears to pass up into them, and to be perfectly conformable to them whilst the very irregular manner in which it overlaps various older groups shews it to be unconformable to all of them. Although this formation is only fully developed to the eastward, a thin band is found, extending to beyond the Nilawán ravine, and even farther west, at the base of the nummulitic group, beds occur probably belonging to the same horizon; indeed, Dr. Waagen considers[3] that this group may be traced throughout the range and across the Indus, where it rests unconformably on the neocomian.

It is almost certain that this olive group of the Punjab Salt Range is the same as the olive *Cardita beaumonti* beds of Sind; the similarity in position and mineral character is striking, and some of the fossils are identical.

[1] Rec. G. S. I., X, p. 224. The block in question is in the Geological Museum, Calcutta.
[2] Waagen. MS. notes.
[3] MS. notes.

CHAPTER XXI.

EXTRA-PENINSULAR AREA.

THE PUNJAB HILLS WEST OF THE JHELUM—(*continued*).

Palæozoic and mesozoic rocks of Northern Punjab — Crystalline and metamorphic — Schistose series — Attock slates — Carboniferous and infratriassic (Tanol group) — Trias (including Rhætic) — Jurassic; Spiti shales — Gieumal sandstone — Cretaceous — Tertiary beds of Punjab generally — Thickness of tertiary series — Distribution of eocene beds — Mari and Bhúgti hills — Sulemán Range near Dera Ghází Khan — Chichála hills and Salt Range — Kohát district — Salt and gypsum — Clays, limestones, and sandstones above the salt — Northern Potwár and Murree hills — Nummulitic limestone of Northern Punjab or hill limestone — Upper tertiaries, Siwaliks, &c. — Distribution — Palæontology — Post-pliocene deposits of the Northern Punjab — Erratics — Indus floods — Fossil shells.

Palæozoic and mesozoic rocks of Northern Punjab.—Before proceeding to the tertiary rocks of the Salt Range and of the Western and South-Western Punjab, it will be well to notice the few details hitherto recorded concerning the older formations of the Alpine and Northern Punjab, comprising Hazára with part of the Murree hills, the Gandgarh, Márgala, and other ranges to the south-west of Hazára, the Chita Pahár, Attock and Cherat hills near the Indus, and the Afridi ranges to the westward. Of the hills of Yusafzai and Swát, north of the Peshávar plain, scarcely anything is known. All the ranges mentioned are north of the peculiar line of dislocation and inversion, already noticed as the northern limit of the upper tertiaries; and all are composed of rocks, which are closely allied to those of the Himalayas, and are for the most part distinct in mineral structure and in organic remains from the strata of corresponding age in the Salt Range. The rocks of Mount Sirbán, near Abbottabad in Hazára, present in many respects an epitome of the geology of the Northern Punjab, and several of the details in the following descriptions are taken from a study of the rocks at that locality by Mr. Wynne and Dr. Waagen.[1]

Crystalline and metamorphic.—The lowest rocks in Hazára are the syenite, porphyritic granitoid gneiss and greenstones of the Pakli

[1] Mem. G. S. I., IX, p. (331). For additional details of the geology of the Northern Punjab, see Wynne, Rec. G. S. I., VI, p. 59; VII, p. 64; X, p. 126; and Q. J. G. S., 1874, p. 61; also Waagen, Rec. G. S. I., V, p. 15; and Denkschr. Kais. Akad. Wiss. Wien., Math. Naturhist. Kl. 1878, p. 10. A sketch is also given in the Punjab Gazetteer, the details for which were furnished by Mr. Wynne.

valley, Súsúlgali, Agror, &c. To what extent these rocks are metamorphosed sedimentary beds, and whether any or all of them are intrusive, is uncertain. The porphyritic granitoid rock with large twin crystals of felspar bears some resemblance to the central gneiss of the Himalayas. Very little more is known of these formations than that they occupy large areas in Northern and North-Eastern Hazára, and that they probably extend thence to the westward. They are a continuation of some of the crystalline rocks forming the axis of the Pír Panjál.

Schistose series.—Between the crystalline rocks and the Attock slates in Hazára there is found an immense thickness of quartzites, dolomites, and schistose beds passing down into gneiss. These rocks apparently rest upon the Attock slates, but the dip seen may be an inversion. They occupy the greater portion of North-Western Hazára and extend down the Indus valley below Turbela. Neither the crystalline nor schistose formations of Hazára extend into the other hills of the Northern Punjab within the British boundary, but both are doubtless continued in the mountains of Yusafzai.

Attock slates.—The next formation has a much wider range. It consists of dark-coloured slates with limestones, some sandstones, and a few intrusions and perhaps contemporaneous beds of basic trap intercalated. These rocks are particularly well seen in the hills on the Indus south of Attock, and have consequently received the name of Attock slates. They are generally remarkable for their dark colour; they are irregularly cleaved, and seldom, if ever, afford good slates for roofing or similar purposes, although their thinly laminated layers are sometimes employed. The limestones vary in texture, being sometimes compact, and occasionally brecciated; they are often altered, and many are dolomitic. They are not often crystalline, although a conspicuous band of sub-crystalline white marble belonging to the present formation extends for some distance along the southern face of the Attock or Mirkuián hills and reappears in the Gandgarh range. The only fossils yet obtained are too obscure for identification, and even such traces of organisms as have been noticed are excessively rare, the slate beds themselves being unfossiliferous.

In parts of Hazára the slates become altered and slightly schistose, as in the neighbourhood of Gandgarh and Haripur. In these hills the typical dark Attock slates are absent or so much altered that they cannot be recognised, the common rock being talcose, silky and schistose from partial metamorphism. Many greenstone dykes and intrusive masses of syenite are found in the schists. In Upper Hazára and Mianjáin, limestones are rare or wanting in the slate series, but they abound in the Gandgarh hills and also near Attock, a few bands of trap being also

found in the Gandgarh range. At Mount Sirbán and around Abbottabad the group consists of slates of a dark colour, sometimes black or purple, with bands of greenish grey sandstone.

Nothing certain is known as to the age of these slates,[1] except that they must be palæozoic, for they are inferior in position and quite unconformable to the infra-triassic group near Abbottabad in Hazára. They are very probably identical with the slates of the Pir Panjál classed as silurian by Lydekker.[2]

The Attock slates occupy a considerable area in Hazára, and form a broad belt between the tract of crystalline and schistose rocks to the north-west and the newer formations to the south-east; one basin of stratified rocks, including limestone, resting upon the gneissose and schistose series of Northern Hazára, amongst the high mountains near the frontier, may also contain representatives of the present formation. The belt of Attock slates continues to the south-west in the Gandgarh hills and in the east and west ranges forming the Cherat and other hills south of Attock and Nowshera, and extending to the westward until the beds are lost near Julozai, beneath the gravels of the Peshávar plain. To the west of Peshávar the rocks are unknown, but the same beds may very probably reappear in the Khyber Pass. North of the cantonment of Nowshera, in the plain of Peshávar, the slates are said to be found near Hoti and Mardán at the base of the Yusafzai mountains.

[1] The suggestion has been repeatedly made by Dr. Waagen, Mr. Wynne and others that the Attock slates are probably represented by beds containing lower silurian fossils in the Khyber Pass. It is not, however, quite certain that the fossils found by Falconer and Vicary in that locality were silurian. The statement that "lower silurian fossils from the Khyber hills were found by Dr. Falconer in the gravel of the Cabul river" was made by Colonel (then Captain) H. H. Godwin-Austen in 1866 (Q. J. G. S., XXII, p. 29). The paper in which this statement was made appears to have been drawn up from field notes without means of access to published information, and no reference is supplied to any original authority. No notice of the discovery of such fossils can be found in Falconer's published writings, and the only original statement in print we have been able to detect is in a foot-note to a paper by Captain Vicary (Q. J. G. S., 1850, p. 45). Vicary himself obtained "a small *Spirifer, Orthis* in abundance, a *Terebratula* and some *Polyparia*" from limestone boulders in the water-courses near Peshávar. In a foot-note he adds: "Dr. Falconer obtained specimens of *Spirifer, Orthis,* and other palæozoic forms from these mountains several years ago." Also in a note by Sir R. Murchison, prefixed to Vicary's paper, the discovery of palæozoic fossils is mentioned. Now it is quite possible that the fossils collected by Falconer and Vicary have been examined and their age determined, but as this is not stated, some doubt remains whether the fossils may not have been carboniferous, as they were said to be by Verchere (J. A. S. B., 1867, Pt. 2, p. 21), the *Orthis* being perhaps *Orthisina* or *Streptorhynchus crenistria,* formerly included in the genus *Orthis.* The chief reason for suggesting the possibility of these fossils having been carboniferous, and not silurian, is that carboniferous rocks are known to occur in the Sulemán Range, whilst no fossiliferous silurian beds have hitherto been discovered in that direction.

[2] Rec. G. S. I., XI, pp. 39, 63, &c.

Carboniferous and infra-triassic.—Carboniferous beds have not as yet been detected with certainty in any locality in the Northern Punjab; a specimen of *Productus humboldti* was found close to Hassan Abdál, by Mr. Lydekker, in a loose block of limestone, but with this exception the carboniferous limestone has not hitherto been traced in the Punjab north of the Salt Range and west of the Jhelum, and it is uncertain whence the block in question was derived. The age of the rocks resting upon the Attock slates at Mount Sirbán, near Abbottabad,[1] has not been definitely ascertained; the rocks in question are quite unconformable to the underlying formation; they are overlaid by the triassic group, and comprise two divisions, the lower consisting of red sandstones, red shales and red siliceous dolomites, with, at the base, a red argillaceous breccia full of fragments derived from the underlying rocks; the upper division composed of dolomites only, lighter in colour than the lower beds, often highly siliceous and of considerable thickness. Above these upper dolomites, again, are some quartz breccias, sandstones and shales, all containing hæmatite: these may belong either to the present or the next group.

These beds have hitherto only been noticed at Mount Sirbán and in other places in Hazára; they may of course be in part carboniferous, but no fossils have hitherto been detected in them.

In South-Western Hazára there is an immense thickness of quartzites, slates, conglomerates, sandstones and magnesian limestones, all somewhat altered and quite unfossiliferous. The relations of these beds are obscure; they appear, however, to overlie the Attock slates. For these rocks Mr. Wynne has proposed the name of Tanol (or Tanáwal) group, from a district in the western part of Hazára near Amb. They form a broad belt, in places 8 miles wide from north to south, extending nearly east and west from the neighbourhood of Abbottabad to the Indus, and probably comprise altered representatives of the infra-triassic rocks of Mount Sirbán.

Trias (including Rhætic).—The next zone is chiefly composed of dark limestone, black or grey, distinctly bedded, with thick zones of massive dolomite, sometimes containing numerous laminæ of opaque white quartz, shales, siliceous breccia, hæmatitic clays, and sandstones. Near Abbottabad, where the series is complete, dolomites form the lowest beds, and are followed by thin-bedded fossiliferous limestones; the dolomites are, however, frequently absent. Above the fossiliferous limestones come quartzites and dolomites of considerable thickness, and above these again thin-bedded limestones and slaty shales, fossiliferous, but

[1] Mem. G. S. I., IX, p. (335).

containing different organisms from those in the underlying portion of the group. The lower sub-division contains two characteristic forms, *Megalodon* and *Dicerocardium*, together with *Chemnitzia*, *Gervillia*, &c., the upper beds contain numerous *Nerineæ*, together with forms of *Neritopsis*, *Astarte*, *Opis*, *Nucula*, *Leda*, *Ostrea*, &c. The lower beds are apparently representative of the "Para limestone" or upper triassic of Spiti, and the higher sub-division of the lower Tagling limestone,[1] or rhætic of the same area.

The triassic rocks are well developed in Hazára between Murree and Abbottabad, and extend from the Mochpura mountains to beyond the trunk road, reappearing in the Chita Pahár, but the outcrops are greatly complicated by disturbance and faulting, especially in the neighbourhood of Murree itself and to the northward. Very little is known with certainty as to the extension of triassic rocks to the south-westward, as it is difficult and often impossible to distinguish the different formations in a mass of unfossiliferous contorted limestones and other rocks, comprising representatives of triassic, jurassic and nummulitic beds. The triassic strata are well developed in the spurs from the Hazára mountains east of Hasan Abdál and Haripur. Here the rocks contain but few fossils, although sufficient to enable their age to be determined. The triassic group is also probably represented by massive contorted limestones in the Chita Pahár range and detached ridges to the north along the southern side of the ranges south of Attock and Nowshera, and extending westward into the Afridi hills.

Jurassic,—Spiti shales.—Above the triassic beds there appears to be a break in the series, and in Hazára the next formation in ascending order consists of jet-black shales with more or less ferruginous concretions. These beds have been identified both by mineral character and fossils with the upper jurassic "Spiti shales," of the Himalayan region, but do not appear to be very thick. Amongst the fossils, *Ammonites*, *Belemnites*, and various *Lamellibranchiata* have been found, some of the most characteristic Spiti species found in the Punjab being *Ammonites* (*Oppelia*) *acucinctus*, *A* (*Perisphinctes*) *frequens*, and *Belemnites gerardi*. The second and last named are also found in Cutch, though in different zones, the former being known from the Umia group, the latter from the Chári sub-division.

The Spiti shales in Hazára are conspicuous from the contrast they afford to the thick mass of limestones ranging from palæozoic to nummu-

[1] See chapter XXVI, on the Himalayan rocks. The lower Tagling limestone was classed by Stoliczka, Mem. G. S. I., V, p. 66, provisionally as lower lias, but he pointed out that it was the equivalent of the Kössen beds, commonly classed as rhætic. The Para limestone, at first classed as rhætic, was subsequently united to the trias.

litic, and forming the bulk of the rocks. Like the underlying trias, the jurassic beds are greatly broken up by faults and dislocations. The Spiti group is well seen on Chamba hill, north of Murree, and has hitherto been found in no district of the Punjab, except the higher parts of the South Hazára mountains.

Gieumal sandstone.—Above the shales in many places, but not invariably, there is found a thick-bedded sandstone, yellowish-brown and ferruginous externally, but bluish-grey when freshly fractured. Occasionally the Spiti shales are wanting, and the rusty sandstones alone represent the jurassic formation. The sandstone closely corresponds in mineral character to the Gieumal sandstone of Spiti, and has been identified with it by Dr. Stoliczka.[1] As a rule, in Hazára, the present formation is not fossiliferous, but some limestones and earthy beds with a few bands of calcareous sandstone can be traced for a long distance on the spur running west by south from the Murree hills to the north of Ráwalpindi, and traversed by the Grand Trunk Road at the Márgalla pass, and appear to be a continuation of the Gieumal sandstone, or they may represent both this band and the Spiti shales. At the Márgalla pass and in some other places, the rock abounds in *Trigonia ventricosa*,[2] the fossil already noticed as characteristic of the Umia beds in Cutch and of the uppermost jurassic zone near Ellore.

The Gieumal sandstone has not been clearly recognised in the Mount Sirbán section, but may be represented by calcareous sandy beds in the upper portion of the Spiti shales. The sandstone is well exposed north of Murree, in places,—always being, however, much crushed and disturbed.

The Jurassic beds have been traced to the south-west along the Márgalla spur, and again south of the Chita Pahár range, south of Campbellpur, to the Indus, and farther west beyond the Indus near Nilabgash into the Afridi country, where the same beds are seen north of Kohát, but very little is known of the exposures. The Spiti shales may perhaps be chiefly represented by limestones, and the Gieumal sandstone by the beds with *Trigonia ventricosa*, but the characteristic appearance of the Himalayan beds is no longer to be traced in this direction.

Cretaceous.—In Mount Sirbán, resting upon the sandy and calcareous strata at the top of the Jurassic group, there is found a bed, 10 to 20 feet thick, of a different kind of calcareous sandstone, ferruginous and weathering of an orange colour. This bed abounds in fossils, mostly coated with iron oxide, and comprising *Ammonites* of cretaceous forms,

[1] Scientific results of the second Yarkand Mission, Geology, p. 11.
[2] See woodcut, *ante*, p. 261.

all belonging to the *cristati* and *inflati* groups, besides species of *Ancyloceras*, *Anisoceras*, *Baculites* and large *Belemnites*, The species have not been determined, but the fauna has a gault facies.

Above the fossiliferous zone there is a group of thin-bedded limestones of grey colour, apparently destitute of organic remains. This may be either cretaceous or nummulitic. It is succeeded by the nummulitic limestone. Cretaceous rocks have hitherto been clearly recognised in only one other locality in the Northern Punjab, north of the Salt Range and Chichâli pass beds; this is close to Kohát, where a band of ferruginous sandy limestone contains some fossils, recognised as of cretaceous age by Dr. Waagen.

Tertiary beds of Punjab generally.—Hitherto, in dealing with the different palæozoic and mesozoic rocks of the Punjab, it has been sufficient to describe isolated outcrops of comparatively small extent; but in treating of the nummulitic limestone and the associated rocks, and to a still greater extent when describing the upper tertiary formations, much larger areas will come under notice, and it will therefore be better to describe each of the two great sub-divisions of the tertiary series, the older tertiary, or eocene, and the newer tertiary, including the representatives of miocene and pliocene formations, throughout the whole Punjab area, commencing at the south. It has already been stated that the miocene marine, or Gáj group of Sind, has not yet been recognised farther north, and although there is very little doubt that the upper eocene Nari group is represented in the Punjab, for some of the characteristic species of nummulites have been brought from Punjab localities, no attempt has yet been made to discriminate the different zones of nummulitic limestone in the northern region by means of fossils. The Ranikot beds, as already noticed, are only known to exist in Lower Sind, but they may be represented by rocks of similar character at the base of the nummulitic limestone in the Salt Range and elsewhere. The only Sind groups which have hitherto been clearly traced to the northwards are the Khirthar or nummulitic limestone proper, and the Manchhar or Siwalik.

Thickness of tertiary series.—The total thickness of the upper tertiary, or Siwalik formation of the Punjab cannot be much less than 15,000 feet, and the Murree beds, into which the upper tertiaries pass, represent about half as much more, so that the whole tertiary series, including the nummulitic limestone and its associated beds, where fully developed, comprises little, if at all, less than 25,000 feet of strata. Of this enormous thickness, all, except the lower 2,000 or 3,000 feet, is destitute of marine remains.

Distribution of eocene beds.—The nummulitic limestone and its associated beds form the higher ranges of the Mari and Bhúgti hills north of the Sind frontier, and extend throughout the Sulemán range, apparently without interruption, from the Sind frontier to Peshá-war. Eocene rocks are said not to occur in the Shekh Budín and other ranges south and south-west of the Bannu plain,[1] but they occupy a very large tract to the northward of the same plain in the Kohát district. They are well developed in the Chicháli and Shingarh range, and they possibly form a great portion of the Afridi hills south of Pesháwar. East of the Indus, the nummulitic group is extensively developed in the Salt Range, and forms the small range of Khairi Múrat south-west of Ráwalpindi. The rocks underlying the Murree beds along the west side of the Jhelum valley belong to the same group, but are poorer in limestone than usual, whilst north of the line of abnormal boundary already mentioned as traversing the Punjáb north of Ráwal-pindi and Kohát, and forming the northern limit of the upper tertiaries, the nummulitic limestone is again largely developed in the Murree and Hazára hills and Chita Pahár, and forms a great band across the province from the neighbourhood of Abbottabad and Murree to the Afridi range south of Pesháwar. In this area the limestone differs from its representative further south, as will be explained presently. A few details of the sections in each area will shew the character of the formation.

Mari hills.—In the Mari and Bhúgti hills north of Jacobabad, the nummulitic limestone forms a number of east and west anticlinal ridges.[2] No lower beds were noticed, and although sandstones rest upon the limestones, it is probable, from the description, that none of them belong to the Nari group, but that they are all Siwalik.

Suleman range near Dera Ghazi Khan.—Not far north of the Mari hills is the section of the Sulemán range near Dera Gházi Khan described by Mr. Ball.[3] Here, again, there is no trace of anything which can be identified with the Nari sandstones, the beds resting upon the nummulitic limestone being described as dark-brownish sandstones in beds of no great thickness, alternating with bright red, greenish and grey clays, probably Siwalik. The lowest beds seen in the whole section of the range consist of a great thickness of sandstones and shales with very few fossils, succeeded by from 1,000 to 2,000 feet of massive limestone with

1 Verchere, J. A. S. B., 1867, XXXVI, Pt. 2, pp. 13-16, and map.
2 Vicary, Q. J. G. S., II, p. 260.
3 Rec. G. S. I., VII, p. 145.

nummulites, &c. On the eastern slope of the hills the nummulitic limestones are much mixed with sandy and shaly beds, but a few miles further to the westward the whole band consists of limestone. The main range of the Sulemán consists of the sandstones and shales underlying the limestones. With the shales some very thin layers of coal are occasionally associated, but none are known to exceed about six inches in thickness, and consequently none hitherto discovered are of any commercial value.

The fossils found in the sandstones are all tertiary species,[1] and one, *Ostrea flemingi*, is in Sind a characteristic Ranikot form. There appears good reason for assigning all the beds noticed to the eocene group, the lower sandstones and shales probably representing the lower Khirthars of the Upper Gáj section described in the last chapter. The nummulitic limestone is evidently a continuation of that forming the Khirthar range in Sind.

Chichali Hills and Salt Range.—No full description of the eocene rocks in the northern portion of the Sulemán range has been published, and it will be as well therefore to proceed at once to the Salt Range and its continuation in the curved ridges of Chicháli and Shingarh west of the Indus. A section of the latter range, taken near Sultan Khel, and about 15 miles north-west of Isa Khel, has been given by Dr. Verchere,[2] whilst the Salt Range rocks have been fully described by Mr Wynne. The section appears much the same throughout, and has a considerable resemblance to that already described in the Sulemán range. There is a bed of limestone several hundreds of feet thick and usually of a light colour, resting upon sandstones, shales and clays, with lignite. The latter pass downwards into the cretaceous olive group, but immediately upon the limestone comes the upper tertiary group, which contains no marine fossils. The Gáj and Nari beds of Sind appear to be unrepresented; there is evidently a break above the nummulitic limestone, and the overlying formation is unconformable, and rests in places upon a denuded surface of nummulitic rocks. The unconformity is also shewn by overlap in several places at the eastern extremity of the Salt Range, and, as already noticed, in the ranges near Shekh Budín, and by the circumstance that the lowest bed of the upper tertiary sandstones sometimes contains pebbles of nummulitic limestone, as for instance near Fadiál, west of Mount Tilla.

[1] The species quoted in Mr. Ball's paper were for the most part only approximately determined.

[2] J. A. S. B., 1865, XXXIV, Pt. 2, p. 42.

The inferior shaly portion of the nummulitic group consists of soft, variegated shales or clays, more or less sandy, with occasionally a pisolitic ferruginous band, resembling laterite, at the base. A similar band is found in a corresponding position in the Sub-Himalayan sections, as will be shewn in the next chapter. Many of the shales and clays are pyritous and decompose readily on exposure, the decomposed shales being burnt and employed in the manufacture of alum. The so-called coal of the Salt Range occurs in the upper part of this lower sub-division, associated with gypseous shales, and is really a lignite of variable purity, found chiefly in thin strings and beds of no great horizontal extent, but occasionally in rather thicker seams, some being as much as three to three and a half feet in thickness. The principal localities are Bhágánwála, Pid and Samundri. Like most of the tertiary lignites, that of the Salt Range is pyritous, and frequently falls to pieces or takes fire spontaneously when exposed to the air. Similar lignite is found in the Chicháli and Shingarh hills west of the Indus. Beneath the coaly shales are white, red and olive sandstones and clays, occasionally with marls or limestone full of foraminifera, and, in the western Salt Range, a thick band of nummulitic limestones occurs immediately below the beds with lignite.

The main band of nummulitic limestone is usually compact, grey or white, occasionally chalky, the upper portion being generally purer and less mixed with shaly or marly bands than the lower. The whole group is fossiliferous, the nummulitic limestone containing the usual fossils, whilst bands containing nummulites and other foraminifera occur amongst the lower shales and sandstones, but more commonly remains of plants, chiefly dicotyledonous, are found in the latter.

The similarity of the section in the Salt Range with that of the Laki range in Sind is very great; the actual beds are thicker in Sind, but in both localities there are olive shales believed to be of upper cretaceous age at the base, then variegated sandstones, alum shales and clays with plant-remains, lignite and gypsum, followed in ascending order by nummulitic limestone. Further comparison of the fossils will, however, be necessary, before the group beneath the nummulitic limestone in the Punjab can be safely correlated with the Ranikot beds of Sind.

Kohat district.—There is another region in the Upper Punjab where the eocene rocks are well developed, and where they have been fully examined and described; this is in the Trans-Indus salt region of the Kohát district,[1] and the section here exposed, although only a few miles distant from parts of the Salt Range, differs in some important

[1] Wynne, Mem. G. S. I., XI, pp. (101)—(330).

points from that just described. The following is abridged from Mr. Wynne's summary of the rocks exposed :—

		Thickness in feet.
Pliocene and Miocene .	*Upper sandstones.*—Soft, grey sandstones, clays and conglomerates	500 to 1,500
	Lower sandstones.—Harder grey and purple sandstones, bright red and purple clays, slightly calcareous and pseudo-conglomeratic bands	3,000 to 3,500
Eocene . .	*Upper nummulitic.*—Nummulitic limestone and some shaly bands	60 to 100
	Red clay zone, or lower nummulitic.—Red clay, lavender coloured near the top, occasionally with *Nummulites*. The lower portion of the red clays in places is partly or wholly replaced by fossiliferous sandstones, thick greenish clays and bands of limestone all containing *Nummulites*	150 to 400
Eocene ? . .	*Gypsum.*—White, grey or black gypsum with bands of clay or shale	50 to 300
	Rock salt.—Thick beds of salt, almost pure. The base not seen	300 to 700 (? 1,200)

The region examined is the hilly tract north of the Bannú plain and of the Chicháli hills, and extending from the Indus, on the east, to the British frontier. The ground is traversed by a series of east and west ranges, chiefly formed of crushed and broken anticlinals of the nummulitic limestone and the associated rocks.

Salt and gypsum.—The rock salt and gypsum at the base of the tertiary series in the Koháț region are very important and remarkable. The salt consists of a more or less crystalline mass, usually grey in colour, with transparent patches, and never reddish, like the salt of the Salt Range. A few earthy bands occur, but the portion of the whole mass too impure to be worked for commercial purposes is but small, although there is no attempt at refining the salt, which is exported for sale in the form in which it is mined. In some places the uppermost layer is dark-coloured, almost black, and bituminous. The quantity of salt is something marvellous; in the anticlinal near Bahádur Khel alone rock salt is seen for a distance of about eight miles, and the thickness exposed exceeds 1,000 feet, the width of the outcrop being sometimes more than a quarter of a mile. Hills, 200 feet high, are sometimes formed of pure rock salt. As a rule, the salt contains sulphate of lime (gypsum), but none of the potassium and magnesium salts of the Salt Range beds.

Above the salt come gypsum and clays, as in the Salt Range, but the colours, white and grey, are very different, and the whole appearance of both salt and gypsum so distinct from those of the ancient salt marl, that although there is no indication of salt beds at a higher level in the Salt Range itself, and although the outcrop of the salt marl close

to Kálabágh on the Indus is only 18 miles from one of the Kohát rock salt regions at Nundrukki, still as a great series of mesozoic and palæozoic beds intervenes, throughout the Salt Range, between the nummulitic group and the salt marl, whilst in Kohát the former rests with apparent conformity upon the gypsum and salt, it appears probable that the salt-bearing rocks in the Kohát district may belong to a very different horizon from that occupied by the same minerals in the Salt Range series. It is by no means certain that the Kohát salt and gypsum are eocene, but, in the absence of any evidence to the contrary, it appears best to class them with the nummulitic beds immediately overlying them.

Clays, limestones, and sandstones above the salt.—Overlying the gypsum, there is usually found a thick bed of deep red clay, the eocene age of which is proved by the occasional occurrence of nummulites in the upper portion. Sometimes the clay is wanting, and apparently replaced by clays, marls, and limestones of a grey or olive colour, and containing nummulites, but the replacement is not clearly proved. Above the red clay zone come earthy limestones, clays, and shales, with nummulites. The main band of limestone is very much thinner than in the Salt Range, but is as usual massive, pale-coloured, and full of *Nummulites, Alveolinæ, &c.* The overlying formation, consisting of sandstones and clays, in which dark red and purple colours predominate, exceeds all the eocene beds in thickness, and is probably, like the sandstones and clays overlying the nummulitic limestone of the Salt Range, really of much later age than the limestone on which it rests.

Pebbles of nummulitic limestone are said[1] to be found in the lowest beds of the sandstone, and some reptilian bones, (not determined,) siliceous fossil wood, and a few ill-preserved ribbed bivalve mollusca have been found, but no characteristic organic remains. The beds resemble Murree beds and pass upwards into undoubted newer tertiary (Siwalik or Manchhar) strata of the usual character, the red colours becoming rarer, and the usual drab grey sandstones and orange or drab clays being the prevailing rocks.

Northern Potwar and Murree Hills.—Along the northern side of the Ráwalpindi or Potwár plateau, and up the Jhelum valley for a long distance north of Murree, there runs the line of abrupt boundary, already noticed as intervening between the tertiary formations to the southward, and the Himalayan or Alpine rocks, inclusive of the hill type of nummulitic limestone, to the northward. It is clear that the tertiary beds seen immediately south of the limit in question must be newer than those to the northward, for marine limestones are intercalated with the lowest clays and sandstones seen south of the boundary, and it is difficult to

[1] Wynne, Mem. G. S. I., XI, p. (170).

understand how two totally different formations could have been deposited contemporaneously on the opposite sides of a line along which there is no evidence of any ridge of older rocks to separate the two areas of deposition. Besides, as has already been stated, the hill form of nummulitic limestone occasionally appears a little to the south of the dividing line, being brought to the surface either by faults or anticlinals, and the newer tertiaries are similarly let in by synclinals, whether faulted or not, to the north of the same limit. Such outcrops are at no great distance from the main boundary, and the rocks are so greatly disturbed and contorted that their relations are obscure. In this case, as elsewhere, the additional knowledge of the distribution of fossils in the older tertiary formations afforded by the study of the Sind rocks has not yet been applied to the Punjab region, whilst the complicated disturbance of the rocks and the comparative paucity or bad preservation of organic remains in the latter country render the correlation of the various strata a work of great difficulty.

Perhaps the most interesting section hitherto noticed is that already referred to, occurring in the anticlinal ridge of Khaíri Múrat about 12 miles south-west of Ráwalpindi. Here clays and sandstones with bands of limestone are seen resting conformably upon a massive clearer limestone; the former rocks being evidently identical with the upper nummulitic beds found south of the main boundary, whilst the latter represents the hill nummulitic limestone.

The eocene beds of the Upper Punjab, south of the line of disturbance, consist of sandstones and shales, very frequently of a red colour, and comprising, towards their base, occasional bands of limestone or marl, with nummulites. Associated with the sandstones, some gypseous shales and bands of gypsum are found, but no trace of the Kohát salt. As already stated, these lower tertiary sandstones are cut off abruptly to the north, and it is not always clear whether they rest upon the hill limestone or are faulted against it; doubtless the junction, whether conformable or unconformable originally, has become complicated by faulting and crushing, but the whole line of boundary has the appearance of a gigantic fault. There is a gradual and complete passage, to the south of this line of fracture, from the beds containing nummulites into the upper tertiary Siwalik rocks, with mammalian bones. As will be noticed in the chapter on the Sub-Himalayan area, very similar beds occur at the base of the tertiary series along the southern foot of the Himalayas in the Eastern Punjab, but in this area representatives of the lower nummulitic limestone are shewn to exist by the fossils occurring.

The rocks at the hill station of Murree have been repeatedly described. The station itself is built on grey and purple sandstones and

deep purplish clays, with occasional concretionary bands. These are the Murree beds of Mr. Wynne, and whilst their lower strata may correspond to the Dagshai sub-division of the Sirmur or eocene series in the Simla hills, it is probable that they represent higher groups also, and they may even comprise strata corresponding to all the Sub-Himalayan beds of the Dagshai, Kasauli and Náhan groups between the Subáthu and the Siwaliks proper. It is evident that no definite line can be drawn, either in the neighbourhood of Murree or to the west of Ráwalpindi, between the eocene beds and the newer tertiaries. Immediately northwest of the ridge on which Murree stands, similar grey and red sandstones and shales, underlying the Murree beds, contain bands of nummulitic limestone. These rocks are supposed to represent in part the Subáthu beds at the base of the Sirmur group,[1] but it is probable that the lower portion of the Subáthu group must be older and representative of part of the hill limestone of the Punjab. The bands with nummulites at the base of the Murree beds are traced at intervals from the country west of the Jhelum to the Potwár, and thence to the westward to beyond the Indus.

Hill nummulitic limestone of Northern Punjab.—The "hill nummulitic limestone," as it is frequently called, consists of a great thickness of dark-bluish grey or blackish limestones, with brownish olive shales. The rock is generally fœtid and massive, with nodular bands, but thick zones of pale-grey splintery limestone also occur. Stratification is sometimes distinct, sometimes obscure. Near Dungagali, between Murree and Abbottabad, some red clays are associated with the hill limestone and appear to be interstratified.[2] These Himalayan and North Punjab beds differ from the nummulitic limestone of the Salt Range and Sulemán mountains, and from the Khirthar limestone of Sind, in colour and structure; but it is far from clear how far the distinction is due to the amount of disturbance and pressure experienced by the northern rocks. The intercalation of shales with the limestone takes place also in Lower Sind and Baluchistán. Similar dark-coloured nummulitic limestones are found in Baluchistán, also in a disturbed region, and all the differences hitherto noticed between the hill nummulitic rocks and their representatives in the Salt Range and elsewhere, except colour, might be attributed to the different amount of disturbance that has affected the two regions. No distinctions have been shewn to exist between the organic remains

[1] See next chapter. The tertiary rocks of the Sub-Himalayan ranges are thus classed in descending order:—

1	Newer; Siwalik	Siwalik. Náhan.
2	Older; Sirmur	Kasauli. Dagshai. Subáthu.

[2] Wynne, MS. notes.

found in the two forms of limestone, except that the hill nummulitic beds contain much fewer and smaller organisms.

The hill type of nummulitic limestones forms a broad belt throughout Hazára and the Murree Hills, from the neighbourhood of Abbottabad, past Murree, and along the spurs traversed by the grand trunk road north-west of Ráwalpindi. The same rock forms the greater part of the Chita Pahár Range, and is continued west of the Indus in the Nilabgash and Afridi hills, which are chiefly composed of this formation. This great belt and the parallel band of the Attock slates to the northward are indeed the leading stratigraphical features of the Northern Punjab, the intervening formations being less prominent, although largely developed locally.

Upper tertiaries, Siwaliks, &c.—It will be unnecessary to devote much space to the description of the upper tertiary rocks, since, despite the enormous area covered by them, and their great thickness, they present a nearly uniform character, and differ but little from the rocks of the same age to the southward in Sind, already described in the last chapter, and from the typical Siwalik series of the Sub-Himalayan region, to which the next two chapters will be devoted.

The passage from the lower into the upper tertiaries throughout the Northern Punjab, so far as the ground has been sufficiently examined, is transitional, with the exception of the boundary to the north of the Salt Range, where, as has already been shewn, the upper tertiary rocks rest unconformably on the nummulitic limestones. But even in this area there is an apparent conformity in dip and strike, the bedding planes of the upper tertiary strata being parallel to those of the nummulitic limestone, and it is not quite certain how many sub-divisions of the tertiary series are wanting.[1] Apparently the lower portion, if not the whole of the Murree beds, including the nummulitic bands at their base,—that is, all those rocks classed as older tertiary that are exposed immediately to the south of the line of discordant junction traversing the Northern Punjab,—are unrepresented to the south of the Ráwalpindi plain. It is probable that a similar deficiency of the middle tertiary beds exists on the flanks

[1] The lowest beds resting upon the nummulitic limestone of the Salt Range are considered by Mr. Wynne to represent the Murree beds, but Mr. Theobald, who has identified the same strata with the middle Siwalik group of the Sub-Himalayan region, considers that even the Náhan group is wanting on the northern slopes of the Salt Range. The fact, determined by Mr. Theobald, that an ossiferous band may be traced not 100 feet above the nummulitic limestone, and that amongst the bones discovered in this band are those of *Mastodon latidens* and *Rhinoceros palæindicus*, renders it probable that the beds resting upon the limestone must be either upper miocene or pliocene, and consequently must belong to a higher horizon than that of the Murree beds generally. Still as the limits of the Murree beds are vague and undefined, it is quite possible that strata, elsewhere classed wi h the Murree beds, may be represented north of the Salt Range.

of the Sulemán Range, and it is highly probable that the sandstones and clays resting upon the nummulitic beds in Kohát are also, as already suggested, separated by a considerable break in time from the typical eocenes.

Throughout the Punjab, as in Sind, the upper tertiary rocks consist of a great sequence of sandstones and clays, surmounted in places by a mass of coarse conglomerate of variable thickness. No satisfactory sub-divisions have been established in this series, although it is certain that a large period of geological time is represented; for the mammalian fossils from the lower portion in the Punjab, as in Sind, include much older forms of life, and resemble those peculiar to the miocene of Europe, whilst in the upper beds living genera are common, although the species are extinct.

The transition from the Murree beds to the upper tertiaries or Siwalik series is marked by a diminution in the prevalence of red clays and sandstones, and by the appearance of bright grey sandstones in great abundance. The sandstones become softer, concretionary bands more numerous, and a few pebbles derived from the nummulitic limestone and Murree beds, together with rounded fragments of quartzite and crystalline rocks, make their appearance. Higher in the section the red clays disappear, and are replaced by orange and grey clays, and there is a gradual passage upwards into the massive conglomerates, which form in many places the upper portion of the whole series. The pebbles of these conglomerates appear to have been derived from the same Himalayan rocks as those now furnishing the materials for the gravel and boulder beds of the Punjab rivers, and it is consequently evident that the rivers in the Siwalik period ran from the north, as they do now.

Distribution.—Commencing, like the eocene rocks, at the southern extremity of the area, the upper tertiary beds form several ranges of hills north of the Upper Sind frontier, between the desert plain of Jacobabad and the ridges of nummulitic limestone; and, to judge by Vicary's section,[1] the higher beds reappear in the valleys between the parallel anticlinal ranges of older tertiary limestone, precisely as in Lower Sind. Passing northward along the boundary of the Deraját, the Siwaliks, although forming only a narrow belt on the flanks of the Sulemán Range in the Siri Pass, west of Dera Gházi Khan, comprise two well-marked sub-divisions; of these the upper, consisting of conglomerates and coarse sandstones, 500 to 600 feet thick, rests unconformably upon the lower, composed of sandstones with bright red, greenish, and grey clays, and attaining a thickness of at least 3,000 feet, and probably more.[2] The only sections recorded have been too hurriedly traversed for more details to be determined, and it must remain for the

[1] Q. J. G. S., II, 1846, p. 261. | [2] Ball, Rec. G. S. I., VII, p. 150.

present uncertain whether any of the intermediate groups of Sind are represented on the flanks of the Sulemán Range.

Passing northward along the Sulemán, the belt of upper tertiary beds appears perfectly continuous. The whole of the Pyzú and Shekh Budín ranges are believed to consist of newer tertiary strata, with the exception of the peak of Shekh Budín itself, and all the north-western slope of the Káfirkot range near the Indus is of the same Siwalik formation. A broad tract to the west of the Bannú plain, the Waziri country north of Bannú, and the western slopes of the Shingarh Range are similarly composed, so that the newer tertiary beds entirely surround, and probably underlie, the Bannú plain.[1] North and north-east of this the upper tertiary formations cover a large portion of the Kohát district west of the Indus, and nearly the whole of the great Káwalpindi plateau to the east of the river, being thrown throughout into a series of great wave-like undulations, the anticlinal and synclinal axes of which have a general east and west direction. Older rocks appear to a large extent in the anticlinal ridges west of the Indus, more sparingly to the eastward, and to the north the upper tertiary area is bounded by the Murree and upper nummulitic beds south of the great line of dislocation.

Palæontology.—It is unnecessary to enter into any detailed account of the organic remains, almost entirely vertebrate, found in the newer tertiaries of the Punjab, because a large number of the same species have also been discovered east of the Jhelum, and it will be better to deal with the Siwalik fauna as a whole. Owing to the similarity of the beds composing the upper tertiary series throughout, and the complicated disturbance which the rocks have undergone in many places, it is very often impracticable to determine the precise horizon at which any particular fossiliferous beds occur, and with a large proportion of the bones hitherto collected, the original locality has been imperfectly recorded. It is therefore impossible to draw up anything like a trustworthy list of the species found in any sub-division of the newer tertiary series; all that is known with certainty is that the majority of the bones found in the Punjab are from the higher portion of the strata.

In one case only has the peculiar miocene fauna of the Sind Lower Manchhar beds as yet been detected in the Punjab, and in this case the exact locality is unknown, but it was in the neighbourhood of Kushálghar, 40 miles south of Attock.[2] Remains of *Mastodon, Dinotherium pentepotamiæ, Listriodon pentepotamiæ, Rhinoceros, Merycopotamus, Dorcatherium, Sanitherium schlagintweitii,* and *Amphicyon*

[1] These details are from Verchere's map, J. A. S. B., 1867, XXXVI, Pt. 2, and from the Atlas sheets of the Great Trigonometrical Survey.

[2] Lydekker, Rec. G. S. I., IX, p. 92. The fossils were first noticed by Falconer, Pal. Mem., I, p. 415.

were found. There can be no question that the beds yielding the above fossils must be at a lower horizon than those from which the bulk of the Siwalik fauna has been procured. It is, however, far from improbable that some of the supposed Siwalik forms come from the same lower horizon, as certain species belong to older forms of life than the majority of the Siwalik vertebrates.

Post-pliocene deposits of Northern Punjab—On the great plains of Ráwalpindi (the Potwár), Bannú, and Pesháwar, extensive deposits of gravel, sand and silt exist. Little is known about later deposits in the Pesháwar and Bannú plains, but those of the Potwár present some features of interest. The surface consists of an alluvial, rather light-brown clay, often containing kunkur, and passing in places into fine silt. Beneath this alluvial deposit there is a mass of gravels and sand, sometimes enclosing boulders of large size. The boulders are not, however, confined to the pebble beds; many have been observed imbedded in fine silt, and this circumstance, together with the great size of many of the blocks found, and the distance to which they have been transported, has induced several observers to attribute the transport of the larger masses to ice, whether floating down a river or in a lake. It has been suggested that the Potwár may have been converted into a lacustrine basin in post-tertiary times by the elevation of the Salt Range and the ridges west of the Indus. There is but little evidence in favour of this view, but still it is not impossible, for, although the pebble beds underlying the finer silt of the Soán valley appear too coarse for lacustrine[1] deposits the silt may be, in part at least, a later deposit.

The post-tertiary deposits are of course quite unconformable to the Siwalik rocks, which had been greatly disturbed and denuded before the later beds were formed. These later beds themselves, however, are occasionally found dipping at a considerable angle, due, it is said, to original deposition. The pebble beds are found around Ráwalpindi and in the neighbourhood of the Indus; they overlie the Rhotas gorge near Jhelum, occur on some of the Salt Range plateaus, and cap the mountain above Kálabágh on the Indus. They are found at a considerable elevation above the present river beds, some fragments of crystalline rocks in the neighbourhood of the Indus, apparently brought down by the stream, having been observed 2,000 feet above the river.

Erratics.—The large blocks attributed to ice flotation appear to have been derived from the Himalayas. They are abundant along the Indus as far up as Amb, on the left bank of the river, in the gorge of the Sirun and for some miles below Attock, around Jhand about 20 miles farther south, and farther still to the southward near the village of Trap

[1] For additional details concerning these alluvial deposits of the Potwár, see Wynne, Rec. G. S. I., X, p. 122, and Theobald, *ib.* pp 140, 223.

on the lower course of the Soán. Some of the blocks have been measured nearly 50 feet in girth and others are even larger. In places such blocks have been found 20 miles away from the banks of the Indus.

Indus floods.—The Indus, as is well known, is subject to extraordinary floods, due to a portion of the upper valley being blocked by landslips or, according to some, by glaciers, and to the sudden destruction of the barriers thus formed. Such floods occurred in 1841 and 1858, and have doubtless taken place in past ages.[1] In the flood of 1841, the waters of the Cabul river were checked and forced backwards for 20 miles by the rise of the Indus; and Drew has shewn that the lake in Gilgit formed by the landslip in 1840-41 must have been 35 miles long, and upwards of 300 feet deep. Enormous quantities of detritus must be carried down by the violent floods produced by the bursting of such barriers, and if, as appears probable,[2] the low temperature of the glacial epoch was felt in India, such lakes at an elevation of 5,000 or 6,000 feet above the sea would have been deeply frozen in winter, and large blocks from the river bed and dam might easily have been embedded in the ice; glaciers also in the North-Western Himalayas must have been more extensive than they now are, and the formation of lakes dammed up by glaciers was probably of common occurrence. Shaw[3] has called attention to the occurrence of heaps of stone and gravel of all sizes brought 80 miles down the Shayok, one of the tributaries of the Upper Indus in Ladák, by blocks of ice; and a similar action on a larger scale on the Indus may easily have supplied the erratics of the Upper Punjab. If the Potwár was a lake, the dispersion of the erratic blocks is easily understood; if not, the area over which the masses of rock are found may be due to variation in the course of the Indus, and to the reversed flow of its tributaries in great floods.

Fossil shells.—In one locality near Fatehganj a number of land and fresh-water shells were found[4] in silt, apparently the same as that in which boulders are elsewhere imbedded. The species found, including *Lymnea rufescens*, *Planorbis exustus*, *Paludina bengalensis*, *Bythinia pulchella*, *Melania tuberculata*, *Bulimus insularis*, *Opeas gracilis*, &c., are the same as are now found common in the country, and it appears doubtful if they would have survived any very great diminution of temperature. At the same time it is possible that the beds containing shells may be of later date than those with boulders.

[1] For accounts of these floods, see Cunningham's "Ladak"; Montgomerie, J. A. S B., 1860, p. 128; Shaw, "High Tartary, Yarkand and Kashghar," p. 433, &c., and Appendix, p. 481; and especially Drew, "Jummoo and Kashmir Territories," p. 414. Numerous references to other accounts are given by the last-named writer.

[2] See *ante*, p. 372.

[3] l. c., p. 486.

[4] The Theobald, Rec. G. S. I., X, p. 141.

CHAPTER XXII.

EXTRA-PENINSULAR AREA.

SUB-HIMALAYAS.

Scanty materials — Provisional limits of Himalayas — Map — General features — Three main divisions. THE SUB-HIMALAYAS: provisional conclusions — General features — Early views — General range of deposits — Classification — Petrology — Chiefly of fresh-water origin — Structural conditions — Faults — Flexures — Middle and terminal Sub-Himalayan regions — The Simla region — Order of description. THE SIRMÚR AREA — Unity of the formation — Subáthu, Dagshai, and Kasauli groups — Relation to the older rocks — Section at Subáthu — Eastern limits of the Sirmúr area — Easternmost outlier of the nummulitic group. SIWALIK SERIES: NÁHAN AREA — The Náhan-Siwalik boundary — The Náhan-Sirmúr boundary. THE JUMNA-GANGES AREA — Composition in relation to the great rivers — Identification of beds in the two zones — Suggested connexion of the two zones in this area. THE GAHRWAL-KUMAUN AREA. THE NEPÁL AREA. THE SIKKIM-BHÚTAN AREA. UPPER ASSAM AREA.

Scanty materials.—Information regarding the Himalayas would probably be the first demand made upon an Indian geologist out of India. In the country itself it has been quite the reverse, and so it happens that up to date this information is most scanty. Regular continuous work in the mountains has not yet been attempted by the Survey, or has only just been begun, in the hope that circumstances will permit of its being continued. The whole information upon which to form an outline of this great geological region consists of Captain R. Strachey's account of a portion of Central Tibet, Stoliczka's observations in Western Tibet, and some casual seasons' work, by members of the Survey, in the Lower and Sub-Himalayan ranges, besides isolated observations of more or less doubtful validity by various travellers, whose principal objects of interest were not geological. As presenting some very marked uniformities of structure, the Himalayas as a whole have no doubt a continuous history; but it would be impossible to make it out from such scant data as exist. Each portion of the Himalayan area has more intricate and intimate relation to the history of the whole mountain region than has, for instance, any particular basin of Gondwána rocks to the history of the peninsular area, so that a description of any part of the mountain chain is more dependent upon a knowledge of the

whole. We can only attempt to indicate such main features as have been determined, and to make some conjectures on their possible connexion. This very preliminary condition of our information must be our excuse for a somewhat irregular method of presentation.

Provisional limits of region.—The area to be included under the word "Himalaya" needs to be specified. As originally applied and accepted by excellent authorities, it would mean only the southern face of the Tibetan plateau; whereas of late by geological writers the name has frequently been used as equivalent to extra-peninsular India, with undefined outer limits. Both senses are about equally inconvenient, in opposite ways. Although the name may be retained in its narrowest sense to distinguish the Himalayan range proper from other ranges of the same apparent system, it is also, as that of the principal, or at least the most famous member of the group, commonly understood to indicate the whole of this more or less parallel system of ranges. In these senses we shall here speak of the main line of snowy peaks between the Bráhmapútra and the Indus as the Himalayan range, and of the Himalayan region as extending from the plains of India to the northern scarp of the Tibetan plateau. It is very possible, or even likely, that this geological region or mountain system, may hereafter be very largely extended; but until this is done upon a basis of observation, and to express a meaning more defined and substantiated than any as yet proposed, it would be more confusing than instructive to adopt a wider definition than that given above. For example, the tertiary rocks of the Potwár and of Hazára (between the Jhelum and Indus) are shewn to be continuous with those of the Sub-Himalayas, and to have been affected by the same disturbing causes; yet it is quite necessary to distinguish by name the two regions, as affected by total and abrupt contrast in the direction of disturbance, and of the resulting surface-features. It is certainly most convenient to restrict the word "Himalaya" in this definite intelligible sense, more or less in agreement with the meaning spontaneously attached to it, rather than adopt a new name for the familiar ground, and extend the old one to a meaning without assignable limits.

The geological contrast between peninsular and non-peninsular India is a very striking one: in the former the sedimentary rocks are almost exclusively of fresh-water formation, while the corresponding deposits in adjoining areas are marine; again, the stratified rocks of the peninsula, from the Upper Vindhyan time, have undergone comparatively little compression or alteration, while very late formations in the adjoining area are universally more or less contorted. We can, however, keep in mind the peculiar characters of the peninsular rocks without

extending the term "Himalaya" on the grounds of such general features as marine origin, and disturbance, regardless of special distribution and structure.

Map.—In the map attached to this work, the Himalayan area is correspondingly more incomplete than the peninsula. The blanks are larger, and such indications as are given are less exact, the lines having been more or less conjecturally extended between the observations made on separate routes. Some important observations by Mr. Lydekker in the Kashmir region that are noticed in the text came too late for insertion on the map.

General features.—So far as known, the Himalayas exhibit more regularity of structure than the Alps. There are, no doubt, exceedingly knotty points to be unravelled, but the continuity and similarity of structure which prevail over large areas greatly facilitate description, and give a promise of an ultimate understanding. On a good physical map, the regularity of the boundary between the mountain region and the plains of Northern India is a very marked feature; a steady gentle curve, convex to the west-south-west, without any interruption from spurs or semi-detached masses. Throughout great distances the main features of the mountains, both of structure and configuration, conform to this outer boundary, and thus we may conveniently take up the description in successive zones.

Three main divisions.—Three such zones or natural divisions, of permanent significance, can be indicated. There is on the south a continuous fringing belt of lower ridges, appropriately known as the Sub-Himalayas, and composed of tertiary rocks. Between this marginal zone and the great snowy range there lies, throughout the whole length of the Himalayas to as far west as the Sutlej, a broad area, some fifty miles wide, consisting of irregular ridges of moderate average elevation, from 5,000 to 8,000 feet—some ranging up to 12,000—all largely made up of crystalline metamorphic rocks, in very obscure relation with some unaltered formations, the latter being for the most part of very uncertain age. This great area, so well defined by position, and characterised throughout by extreme complexity of structure, may appropriately be distinguished as the Lower Himalayan region. Although of course the most accessible and the most frequented part of the mountains, it is the least understood. The great snowy range of the Himalayas proper belongs to what may be conveniently distinguished as the Central, or Tibetan, division of the mountains, which is characterised on the large scale by several parallel axes of gneissic rocks and intervening synclinal basins of little-altered, fossiliferous formations. To the west of the Sutlej, and actually on the strike of the

great Himalayan range, the hills next to the tertiary zone have this latter type of structure, and must be classed in the central division. This feature and the corresponding disappearance of the whole Lower Himalayan region at the Sutlej point to a fact which must be constantly kept in mind—that our observations and descriptions refer chiefly to the (partially) terminal portions of the great Himalayan region, most of the middle Himalayas, in Nipal and to the north of it, being unknown to us; so that the divisions and characters adopted in the north-western portion may be inapplicable to the mountain region as a whole. It is, however, to be observed that the fundamental structural characters, from which the history of the mountains is to be made out, may be better exhibited where dying out than in the more elevated middle regions, where a deeper and intensified phase of disturbing conditions would be exhibited.

THE SUB-HIMALAYAS.[1]—**Provisional conclusions.**—The Himalayas being generally supposed to have been upraised in late tertiary times, the study of the tertiary rocks ought to be of special importance, as embracing the most active period in the history of the mountains. Since our sketch of this history cannot be very formal or conclusive, it may assist comprehension to indicate at the outset the provisional views suggested by the observations that have been made, up to the present, in the Sub-Himalayan region. If these points do not specifically agree with current anticipations, they quite bear out the important part taken by the tertiary formations, and the mention of them here will give a meaning and an immediate interest to the descriptive details. Some of these provisional conclusions depend more or less upon single sections, on the report of a single observer, and the verification of them should be an object with every competent explorer, either to confirm or confute. To provoke this desirable service we will give dogmatic prominence to the crucial points. It will be shewn—

(1), that immediately preceding the lower tertiary (nummulitic) period, the area defined as the Lower Himalayas must have been exposed to denudation as part of a land of doubtful configuration;

(2), that the very ancient, slaty rocks of that land upon which, after depression, the marine nummulitic deposits were laid down, had then undergone little or no contortion, where they are now most contorted;

(3), that during the deposition of an immense thickness of the upper tertiary deposits, the Himalayan region was already

[1] For published descriptions of the Geology, see Mem. G. S. I., III, Pt. 2; Rec. G. S. I., IX, p. 49.

defined as an area of denudation in which the great rivers were the same as are now found there;

(4), that the topmost beds (Upper Siwalik) of the Sub-Himalayan tertiary series have undergone extreme disturbance;

(5), that the operation of the forces by which this total of results was accomplished must have been most gradual.

General features.—By abrupt difference of elevation and by contour, the Sub-Himalayan hills are everywhere easily distinguishable from the much higher mountains to the north of them. They very commonly present a steep face to the south, with a more gentle inner slope; and as a general rule they consist of two ranges, separated by a broad flat valley, for which the native name "dún" (doon) has been adopted in India. When the outer of these ranges is wanting, as is the case below Naini Tál and Dárjíling, the whole geographical feature might escape notice, the inner range being confounded with the spurs of the mountains. From a point of view whence all the surface features of this inner range can be seen, it will, however, generally be observed, that the hills are not branching extremities of the spurs from the main range, but true longitudinal flanking ridges, separated from the higher range by a line of gaps and gorges; or at least there will always be noticed a rapid increase of elevation immediately inside the tertiary boundary.

Two places are known, on the Bhútan frontier, where even the inner Sub-Himalayan range is wanting, and the marginal slopes of the plains reach to the base of the Lower Himalayan region; but with these exceptions the fringe of tertiary rocks is, so far as we know, continuous for 1,500 miles, from the Bráhmapútra to the Jhelum, which are the limits of the Himalayan region proper, as here restricted. West of the Sutlej, where the Lower Himalayan area ends, there is an equivalent increase in the width of the Sub-Himalayan zone, made up by a repetition of low ridges and intervening dúns.

Early views on Sub-Himalayas.—Soft, massive sandstone is the prevailing rock of the Sub-Himalayan ranges, but associated in very variable proportions, according to position, with conglomerates and clays. Owing apparently to some suspected connexion with the rock-salt deposits of North-Western India, these sandstones were considered by the early observers to belong to the New Red Sandstone of the European scale of formations. The Vindhyan rocks on the south of the plains were regarded at the same time as Old Red Sandstone; and on the strength of these identifications borings were recommended, if not actually undertaken, along the margin of the plains, to find the carboniferous formation

with its coal.[1] It was the discovery of the famous Siwalik fossils in the outer range of the hills that established the true age of these rocks. Sir Proby Cautley (then Lieutenant Cautley, R.A.) seems to have been the original discoverer of those fossils, prior to 1832[2]; and the great collections were subsequently made by him and Dr. Falconer, and described by the latter, chiefly in the Fauna Antiqua Sivalensis and Palæontological Memoirs. Long after the publication of the tertiary age of the Siwalik rocks, until the examination of the ground by the Survey, the sandstones of the inner range flanking the mountains were still regarded as secondary.

General range of these deposits.—The whole of the Sub-Himalayan zone is formed of these tertiary rocks, with the exception of some inliers of palæozoic limestone in the north-west, where the area is broadest. At this western extremity of the range, on the Jhelum, the whole sedimentary series undergoes an abrupt change of strike, and the tertiary formations, without break of continuity, thus sweep into the Potwár (the upland north of the Salt Range) and across the Indus, passing down into Sind.

In the other direction, the breach of continuity mentioned in the Sub-Himalayan hills on the Bhútan frontier applies also superficially to the rocks, no outcrop of the sandstones having been detected in this position. It is thought that they are only concealed, having been denuded, and then covered up by the diluvial gravels; but it may be that they are altogether wanting, for in this neighbourhood, in Lower Assam, detached hill masses, formed of gneissic rocks of the peninsular type, approach nearer than anywhere else to the Himalayan border. At one spot, indeed, on the east bank of the Raidak (E. long. 89° 47′), Mr. Mallet observed a small boss of this southern gneiss far within the tertiary zone, and only a few hundred yards from its inner boundary.[3] The sandstone intervened between this boss and the very different metamorphic rocks of the mountains; its contact with the gneiss forming the boss was not seen, but we may presume that the relation is one of simple superposition, and that we have here the local extra-

[1] In Notes on the Economic Mineralogy of the Hill Districts of the North-Western Provinces of India, by E. T. Atkinson, B.A., F.R.G.S., Bengal Civil Service, 1877, the following remark occurs:—"But it has never yet been settled whether coal does or does not exist in Kumaun, and until this question has received the attention due to it, the eventual absolute success of the Kumaun mines must remain problematical" (p. 7). There is no further allusion to coal, to indicate upon what facts this hope of its occurrence is based. It may be only a survival of the primitive idea mentioned in the text.

[2] Jour. As. Soc., Bengal, Vol. I, p. 249, 1832.

[3] Mem. G. S. I., XI, 44.

Himalayan base of the tertiary series, the natural junction of such extreme types of rock indicating an equivalent geological break, even the nummulitic beds being absent. These gaps in the tertiary zone do not, however, quite correspond with the nearest approach of the southern gneissic rocks, but lie somewhat to the west; and it may be more to the point to notice that they occur exactly in front of the great gap between the Assam range and the Rájmahál hills through which all the Himalayan drainage passes to the Bay of Bengal. It seems at least probable that the sandstones once were continuous across these gaps, though no remnant of these tertiary beds may now be left beneath the superficial deposits; and at all events it is certain that the Sub-Himalayan hills and rocks occur again in full force and characteristic form through Upper Assam to the Bráhmapútra, where, as on the Jhelum at the western extremity of the range, they bend round across the head of the Assam valley, and there conform to a system of disturbance having a totally different direction from that of the Himalayas proper. All this takes place in a very remote wild country, inhabited by savage tribes, outside the limits of British occupation, so no details of the feature are known beyond the facts given.

Besides the case described in Lower Assam, the only other position within or close to the Sub-Himalayan region where we find an extra-Himalayan base for the Sub-Himalayan series is in the Punjab, on the south side of the Ráwalpindi plateau, or Potwár, where lower or middle Siwalik sandstones rest with quasi-conformity on the nummulitic limestone capping the older fossiliferous series of the Salt Range, as already described in the preceding chapter. Over all the intermediate country, from east to west, the southern limit of the tertiary rocks is altogether a matter of conjecture, for no trace of them is found along the southern edge of the plains, where from beneath the alluvial deposits the most ancient formations of peninsular India crop out; unless, indeed, we are to recognise them, as has been suggested, in the deepest beds of these plains deposits themselves.

Classification.—From the familiar terms "nummulitic" and "Siwalik" used parenthetically in preceding paragraphs, it may be observed that the Sub-Himalayan system contains a pretty full representation of the tertiary series as generally understood, the former deposits being eocene and the latter in part pliocene. The deposits do ample justice to this extended period, their aggregate thickness being computed as between 12,000 and 15,000 feet, or very much more if we take the maximum thickness of different portions in different positions.

Within this region the vertical limits of the series are very well defined, the nummulitic beds at the base are everywhere in abrupt

contact with immensely older rocks, presumably palæozoic; while the topmost Siwalik beds are as often as not vertical at the edge of the plains, and are thus in the sharpest possible stratigraphical contrast with the post-pliocene and recent deposits. For use within this special region the following classification may be adopted for the Sub-Himalayan formations :—

SUB-HIMALAYAN SYSTEM.	Siwalik series	Upper.
		Middle.
		Lower (Náhan).
	Sirmúr series	Upper (Kasauli).
		Middle (Dagshai).
		Lower (Subáthu : nummulitic).

The enunciation of a classified list of formations ought at once to facilitate the progress of description. We should be able to take up each so-called group and point out its exact range. For the bottom and top divisions of our list—the Subáthu and the Upper Siwalik—this might be roughly done; but we should utterly break down in attempting a continuous delineation of the middle zones. This failure is highly suggestive of error; but recognised confusion may be a safer state of progress than imposed order; and the compromise to be suggested is that no single group-list will ever suit the different sections of the Sub-Himalayan zone; *e. g.*, the break between the Siwalik and Sirmúr divisions, which is the most marked feature in the Simla region (according to the interpretation given), certainly disappears before reaching the Jhelum. Such discrepancies will not surprise any one who can perceive that the Himalayas have been in great part formed synchronously with the deposition of the tertiary series between the Subáthu and Upper Siwalik groups.

Under these difficult circumstances we must crave the reader's indulgence for a less regular form of treatment than has been followed in the preceding chapters, and for the introduction of discussion upon elementary questions not hitherto mentioned, because these are of crucial importance in the mountain-sections. A brief abstract account of each division will be given, and for further details reference must be made to the descriptions of the separate areas.

Petrology.—Sandstone immensely preponderates in the Sub-Himalayan deposits, and is of a very persistent type from end to end of the region and from top to bottom of the series. Its commonest form is undistinguishable from the rock of corresponding age known as Molasse in the Alps, of a clear pepper and salt grey, sharp and fine in grain, generally soft, and in very massive beds. The whole Middle and Lower Siwaliks are formed of this rock, with occasional thick beds of red clay

and very rare thin, discontinuous bands and nodules of earthy limestone, the sandstone itself being sometimes calcareous, and thus cemented into hard nodular masses. In the Sirmúr group generally, and locally in the Lower Siwaliks, the sandstone is thoroughly indurated and often of a purple tint, while retaining the distinctive aspect. In the Upper Siwaliks conglomerates prevail largely; they are often made up of the coarsest shingle, precisely like that in the beds of the great Himalayan torrents. Brown clays occur often with the conglomerate, and sometimes almost entirely replace it. This clay, even when tilted to the vertical, is undistinguishable in hand specimens from that of the recent plains deposit; and no doubt it was formed in a similar manner, as alluvium. The sandstone, too, of this zone, is exactly like the sand forming the banks of the great rivers, but in a more or less consolidated condition. Thus it was suggestive, and not altogether misleading, to say that the Siwaliks were formed of an upraised portion of the plains of India.

It is only the bottom member of the series that departs widely from the prevailing type of Sub-Himalayan rock. The Subáthu group with nummulites is, of course, marine. Its most distinctive, though not most abundant rock, is a thin-bedded limestone, more or less pure or earthy, associated with clear brown, olive and red, fine crumbling clays; and these latter pass up by interstratification into the strong red clunchy clays, alternating with sandstones, of the middle Sirmúr horizon.

Chiefly of fresh-water origin.—The fresh-water origin of the Siwalik formation seems almost as indisputable as the marine origin of the Subáthu beds; yet, until lately, it has been usual to consider the Siwaliks marine. The notion was probably a relic of the opinion, that a water basin was an essential condition of the extensive accumulation of deposits, and that a sea margin would be required for such a great spread of shingle as that of the Siwalik conglomerates. The same opinion, on the same grounds, has been extended to the plains deposits themselves.

The continued experience that the fossil remains in these tertiary strata are exclusively of land or fresh-water organisms, made this view untenable; and in time it came to be realised that the deposits themselves bear out the same opinion: the mountain torrents are now in many cases engaged in laying down great banks of shingle at the margin of the plains, just like the Siwalik conglomerates; and the thick sandstones and sandy clays of the tertiary series are of just the same type of form and composition as the actual deposits of the great rivers.

Beds of this character alternate with the upper beds of the Subáthu group; so it seems probable that from early tertiary times the sea has been excluded from the Sub-Himalayan region, and that the whole of

the Sub-Himalayan deposits, above the Subáthu group, are fresh-water and fluviatile, and formed on the surface of the land. They are in fact subaërial formations, like the river alluvium and bhábar deposits of the present day.

The striking agreement in character between the Sub-Himalayan rocks and the actual deposits now in progress of formation from Himalayan debris, at once suggests that the mountain border must have been to some extent defined, and the Himalayan area undergoing denudation, from early tertiary times; and it will be seen from the distribution of the Siwalik conglomerates, that during the later tertiary times the configuration of the mountains must have been very similar to what it is now.

Structural conditions.—The validity and meaning of the classification of the Sub-Himalayan tertiary formations depend so much upon the interpretation of certain leading and constant features of the sections, that it is absolutely necessary to preface the descriptions of these features by a brief discussion of certain elementary stratigraphical characters of somewhat exceptional application. Although, of course, not required for the experienced geologist, these explanations will surely be of use to some who may attempt to extend our observations.

The distinction between the original relations of rocks, those resulting from the conditions at the time of formation, and the relations induced by subsequent disturbance is perfectly clear in thought and in fact. In practice, however, it is often most difficult to discriminate between these relations, and the confusion is at the root of many a disputed position. The reader of the foregoing chapters may already have perceived this in connexion with the question of the nature of the basins of Gondwána rocks (pages 103-106). In the Himalayan sections it is of special difficulty and interest, as bearing upon the question of mountain formation; and some preliminary indications are necessary to a comprehension of the case.

The most remarkable structural features in the Sub-Himalayan zone consist of long lines of abrupt contact of highly contrasting rocks, in which, as a rule, the newer strata dip towards, and so apparently under, the older; and in most cases the beds on both sides of the junction are in normal order, *i.e.*, not inverted. As exposed in the sides of steep valleys, the V-shaped outcrop of the plane of contact, pointing up the valley, towards the older rocks, shews indisputably that these latter are to that extent superposed on the newer. It is quite certain that this could not have been an original relation of these contiguous formations.

Faults.—In every region which has undergone disturbance to any extent there occur what geologists call faults—fissures along which the

rocks on either side have moved up or down, or up on one side and down on the other, resulting in a separation of the once continuous strata. Side movement along the fissure may also occur, but this effect is not here considered. When the fissure is vertical, the displacement is altogether vertical; but when the fissure has a slope, there is a horizontal effect also: if the mass on the upper side move downwards, the ends of the broken beds retreat from each other, leaving a gap between the broken ends of the several strata; but when the opposite movement occurs, the ends of the several beds overlap, so that the newer underlies the older, and a vertical line would pass twice through the same beds on opposite sides of the fault. This latter kind is the least common, and so has come to be called a *reversed* fault. It is clear that horizontal pressure on opposite sides of a sloping plane of fracture tends to produce reversed faults, the movement on the inclined plane being always in the direction of the force producing it.

The feature mentioned as so common on the Himalayan border has *primâ facie* the appearance of a reversed fault. Off-hand judgments are, however, very dangerous in complicated cases: a fault that was originally vertical and normal might easily assume the condition of a reversed fault by a suitable tilt in the whole mass, and it is easy to see that the original relations of rocks might be similarly deformed beyond *primâ facie* recognition. The word "deposit" suggests chiefly a floor of deposition, and other limiting conditions are liable to be lost sight of. We hear, indeed, of geological shores, but chiefly in the sense of shallow bottoms; yet all of us are familiar with cliffs and slopes of every degree. Although due to erosion and always, as cliffs, subject to denudation, these may also form surfaces on and against which deposition may take place, and the resulting rock-feature must always bear more or less resemblance to a fault—discontinuous rocks in steep juxtaposition. It is, moreover, certain that subsequent compression might in this case also produce the resemblance of a reversed fault—the overhanging of older upon newer strata.

These evident chances of deception call for careful examination of the ground in certain cases, and we are not without tests, more or less trustworthy, according to circumstances. A fault, as such, unless it occurs in the bedding or along some other plane of original contact, implies the same series of rocks on each side—that any bed on the downthrow side can be found on the upthrow side, unless removed by denudation; and that any bed on the upthrow side can be found on the downthrow side, unless buried out of sight. Straightness of direction is another special original character of faults, any departure from which

would generally be due to inequalities in the resisting medium when the fracture was made; and in proportion to the magnitude of the fault this interference would probably be ineffectual. Another important criterion between a faulted and an original contact should be found at the very contact itself, and in proportion to the magnitude of the fault. It is certain that slips do occur in the interior of rock masses with scarcely any perceptible effect of crushing or of friction; and it is intelligible how this may take place; but there must be a general tendency to such effects, and often they are most marked. In the case of these reversed faults—the result of lateral compression—the friction must be prodigious, and its effects conspicuous. On the other hand, a steep surface of original contact, by deposition, would have a quite different appearance; although this, too, would be greatly disguised by subsequent compression, such as would convert a normal into a reversed slope of the junction. The leading structural lines so marked in the Sub-Himalayas exhibit mixed characters; in some the evidence is very strongly in favour of faulting; in others there is very decided evidence that the feature is principally aboriginal.[1]

Flexures.—These special lines, the right comprehension of which is so essential to an understanding of the mountains' history, are in some cases traceable into connection with the known direct effects of disturbance, which in this region observe a decided prevailing type, that of normal flexures with the axis-plane inclined towards the mountains.[2] The familiar form of the Sub-Himalyan hills is a direct result of this structural character. The detached Siwalik ranges are mostly formed of a single flexure, the steep southern or outer face corresponding with the high dip of the beds; or else, the strata on this, the southern, side of the axis have been removed by denudation, exposing the scarped edges of the gently sloping strata on the north side. This low dip becomes more or less horizontal, and so forms the area of the typical dún, or longitudinal valley, of the Sub-Himalayan zone.

Middle and terminal Sub-Himalayan regions.—As there are gaps of some 50 to 200 miles between several of the known sections of the

[1] In geological language, this word must mean—from the commencement of the relation, *i. e.*, from the date of formation of the newer rock.

[2] Professor H. D. Rogers' classification (Geology of Pennsylvania, 1858) of the undulations of strata will be found most useful: the *symetrical* flexure, when the inclinations is the same on both sides of the axis; the *normal* flexure (so-called, perhaps, because, the most common in mountain regions), when the dip is greater on one side than on the other; and the *folded* flexure, when the steeper dip has been pushed beyond the vertical, the beds on that side being then inverted. The *axis-plane* is the plane bisecting the angle between the opposite dips. To the above we may add the *monoclinal* flexure, when the beds on one side are horizontal.

Sub-Himalayan zone, the description must be similarly broken, and this method will also best suit the imperfect state of our knowledge even where observations have been continuous. The conditions of the ground lend themselves to this method. One very marked natural division of the Sub-Himalayan rock-features corresponds to the termination of the Lower Himalayan region, about the seventy-seventh parallel of east longitude. East of this line, only the upper tertiary rocks are found, forming a mere fringe to the Lower Himalayas, and consisting often of a single range of low hills immediately flanking the mountains; whereas, to the west, there are always several ranges of Sub-Himalayan hills, and the zone is sometimes 60 miles wide. As the word *central* has been already applied to a division of the mountains in the sense of axial, and as distinguished from lateral, so the word *middle* will be used in a transverse sense, as distinguished from terminal; and thus the contrast here indicated is between the terminal, north-western, portion of the zone and the middle portion. We do not know enough of the far eastern region to say whether there are any corresponding terminal features in that direction.[1]

The Simla region.—The discrepancies that have been mentioned in the classification of the tertiary series on different sections are chiefly connected with this general change of the mountain features, and so the position is one of special importance. For the older rocks, also, the terminal area of the Lower Himalayas will be shewn to be of peculiar interest, so it will be convenient to give this tract a distinguishing name as the Simla region; the name being, of course, derived from the favourite hill station which stands in the middle of the area, on the watershed between the Sutlej and the Jumna. It is here we find the original type area of the Sirmúr series, where a remnant of these lower tertiary formations has been elevated on the margin of the Lower Himalayas. To the east the series disappears altogether, and to the west it passes down into the Sub-Himalayan zone. Corresponding to this elevation of the lower tertiaries, we find here a total separation of them from the upper series; and there is evidence to suggest that the relation between

[1] The words *inner* and *outer* are of frequent use in the description of mountain structure. With some writers they have reference to a point external to the range, to an imaginary centre of dispersion of the disturbing action. In the text these words will be used with reference to central (axial); and as our description chiefly refers to the southern face of the mountain region, this use will not conflict with that other sense of the words, for from that point of view the wave of Himalayan disturbance is supposed to have come from the north.

Longitudinal and *transverse* or *lateral* are also terms of frequent use in descriptions of mountain structure; they refer to directions with, or across, the axis of the range.

the two is of the nature of an unconformity. Here, too, we find evidence for at least a local unconformity in the upper tertiary, or Siwalik series. It seems possible that these two important features may be generally characteristic of the whole middle Himalayan area; while it is certain that to the north-west neither supposed unconformity is maintained, and other structural features are introduced different from any observed in the middle area.

Order of description.—Following these indications, we will first examine these apparently more decisive sections of the Simla region, and then the other areas of the middle Himalayan ground to the east. We will then return and describe the expanded tertiary zone to the north-west, in the Kángra district and the Jamu (Jummoo) hills.

THE SIRMUR AREA.—The typical area of the Sirmúr series is not in the Sub-Himalayan zone, but on the margin of the Lower Himalayas, at their extremity, where the boundary sweeps round to the north up to the base of the Dhauladhár. At this edge of the mountains, convex to the south-west, a remnant of the lower tertiary formations has been preserved, upraised on a basis of the old rocks. The occurrence forms thus an exception to the complete correspondence between the expressions Sub-Himalayan rocks and Sub-Himalayan area; and we have to put up with the anomaly of taking our type section of the lower series of the Sub-Himalayan system from the Lower Himalayan area. Although spoken of as a remnant, the formation here occupies a considerable extent of ground, stretching from the Sutlej for 70 miles to the eastward to within 15 miles of the Jumna, and locally as much as 10 miles wide. All the east end of the area is in the Sirmúr State, so this name has been taken for the formation.

Unity of the formation.—In a more important sense than relative size, the tertiaries of the Sirmúr area are not properly a remnant. Although the latest beds of the series are only found in a few places, they form, with the lower deposits, a series of very complete facies and unity, presenting a gradual passage, by interstratification, from exclusively calcario-earthy marine beds at the base, through clays and sandstones, to an exclusively sandy band at top, in which fossil leaves of plants are locally abundant, suggesting the natural local consummation of a continuous process of deposition. This character is of much importance in discussing the relation to the Siwalik series immediately to the south.

Subathu, Dagshai, and Kasauli groups.—The nummulitic rocks of Subáthu were first described by Major Vicary in 1853[1]; and

[1] Q. J. G. S., IX, 1853, p. 70.

the fossils collected by him were included in the *Description des animaux fossiles du Groupe Nummulitique de l'Inde* (1853) by D'Archiac and Haime, from which work the following list is taken. The authors remark upon the great contrast between these fossils and those from the nummulitic beds of the Salt Range and of Sind; a contrast especially shewn by the total want of corals, bryozoa, echinoderms, and crustaceans in the collections from Subáthu. This discrepancy may perhaps to some extent be accounted for by the prevailing muddy character of the Sub-Himalayan nummulitic deposits as compared with those to the south-west.[1]

GASTEROPODA.

Physa ? nummulitica.
e * *Natica glaucinoides.*
e * *N. mutabilis.*
e * *N. Roualti.*
e *N. epiglottina.*
N. cypræformis.
Turbo oldheimi.
Turritella subathooensis.
T. subfasciata.
Cerithium jelumense.
C. stracheyi.
C. hookeri.
Fusus malcolmsoni.
F. macclellandi.
F. obscurus.
Rostellaria rimosa.
Buccinum, sp. indet.
Voluta multidentata ?
e *Terebellum fusiforme.*
e *Ancellaria olivula.*
Conus, 2 sp. indet.

LAMELLIBRANCHIATA.

Panopæa ? subelongata.
* *Corbula subexarata.*
Donax crassa.
Cyprina ? subathooensis.
C. transversa.
C. semilunaris.
Venus gumberensis.
V. subgumberensis.
V. pseudonitidula.
V. everesti.
V. subeveresti.
V. subcyrenoides.
V. nucleus.
V. semicircularis.
* *Cardita subcomplanata*, var.
C. depressa.
C. mutabilis.
Cardium jacquemonti.
Cypricardia vicaryi.
C. faba.
Arca, sp.
Avicula rutimeyri.

FORAMINIFERA.

e * *Nummulites lucasana, var.*
e * *N. beaumonti.*
e * *N. spira.*

Those marked *e* occur in Europe.
" " * " Sind.

[1] Complete reliance cannot be placed in the recorded distribution of these fossils. In the brief stratigraphical sketch given on pages 175 and 176 of the work, there are several important errors, none of which occur in Major Vicary's own account (*l. c.*) published in the same year; such as the occurrence of large mammalian fossils in beds immediately overlying the nummulitics near Subáthu. Reference was made to Major Vicary on these points: he declared the statements to be erroneous, but could not explain the confusion that appeared in the account of MM. D'Archiac and Haime. (Mem. G. S. I., III, pt. 2, p. 93, note).

In the Sirmúr area, the prevailing rock of the Subáthu group is a fine, pale yellowish-brown, crumbling clay with occasional calcareous bands, or locally some thin beds of purer limestone; dark-greenish shales and sometimes harder sandy beds occur. Even within this small area the thickness of the group varies from 200 to 1,000 feet, as well as can be estimated in these very disturbed sections. At the top of the group, beds of red clay or shale alternate with the typical Subáthu rocks, and more or less rapidly increase to the exclusion of the others, with the introduction of thick beds of hard purplish sandstone. Thus a gradual transition takes place into deposits of strikingly different aspect. The Dagshai ridge is entirely made up of these red clays and hard purplish sandstones of the middle Sirmúr group, which must have a thickness of 800 to 1,000 feet. The sandstone has quite the composition and texture of the Siwalik rock, and when from any local cause it is less indurated and has lost its colour, the two are undistinguishable. The red clays gradually disappear, and on the Kasauli ridge, and elsewhere, we find some 600 to 800 feet of sandstone, with only occasional partings of grey sandy shale, in which the leaves of plants are locally abundant.[1]

The separation of the Kasauli and Dagshai horizons is, of course, less marked and less significant than that of the Subáthu group; and the two would go well together as upper Sirmúrs, as distinguished from the marine nummulitic deposits forming the lower part of the series. But, as suggested already, the further distinction is important for purposes of local comparison. A thickness of 2,000 feet is the least assignable for the series in the Sirmúr area, the whole mountain mass being formed of it, from the water level in the Sursulla, at an elevation of about 2,000 feet, to the summit of Kasauli (6,335), within a horizontal distance of less than two miles; but the disturbance is everywhere excessive.

Relation to the older rocks.—The first thing to notice is, that the Sirmúr rocks in the Simla region do not rest upon the top group of the older formations. All the strata are so tremendously crushed together, and the junctions for the most part so steep, that the true relation is not apparent at once. The newest group of the old, pre-tertiary, rocks is unquestionably the massive limestone, underlaid by a great thickness of flaggy slates, forming the conspicuous hills of

[1] Two of these localities may be indicated: one is on the lower Mall, at Kasauli, at a projecting angle about a quarter of a mile south of the water tunnel; the other is some miles north of Kasauli, on the Budi road, near the stream in the chief re-entering angle on the east side of the main ridge. The leaves were roughly identified as belonging to the natural families of *Sapindaceæ, Ericaceæ, Lauraceæ, Moraceæ, Cycadeaceæ, Coniferæ, Palmaceæ, Cyperaceæ*, and *Gramineæ*.—Mem. G. S. I., III pt. 2, p. 97.

the Bój and the Król on the new road to Simla. The main tertiary outlier lies to the south of the Bój, the junction passing under the flank of this mountain and along two spurs, the opposite sides of which are formed of highly contrasting formations, with converging dips, flaggy slates on the north-east, and thick sandstone and red clays on the south-west. But the deep valley between the Bój and Król is also occupied by the bottom tertiary deposits. In the very great majority of exposed sections of the contact, it would be impossible to assert positively that the existing relative positions are not due to faulting; but crucial sections are to be found; and one such would be enough to prove that the old rocks had been deeply denuded before the tertiary period.

Section at Subathu.—Within the station of Subáthu a typical section of this kind is well exposed. The small flat space north of the parade-ground is on a surface of soft nummulitic clay, the outcrop of steeply compressed beds, on both sides of which the slaty flags protrude. Down the sides of the valley to the north-west the contact can be followed continuously, and it is unmistakably an original junction. The feature is a synclinal fold, and the same bottom layer of the Subáthu group, a peculiar pisolitic ferruginous clay, is in contact with the slates throughout. The horizon of these slates is many hundred feet below the base of the Król limestone; it may even be below the Blaini limestone, which is itself at least 1,000 feet below the Król: these details remain still to be worked out.

Another very important relation is apparent in this section at Subáthu: the same synclinal fold affects the slate series, approximately the same layer being at the contact throughout; from which conditions we may certainly conclude that these slates were still approximately flat at the beginning of the tertiary period. This zone of the mountains is at present one of extreme contortion, most, if not all, of which therefore dates from that late period.

There is other evidence from the Subáthu sections that the prenummulitic surface here was very, and suddenly, uneven. In the little section of local bottom beds near the parade-ground, including altogether, perhaps, 200 feet in thickness, the red clays of the middle Sirmúr, or Dagshai, type are already represented, and this group is found in force ascending the ridge to the south-east; while in the steep flanks of the ridge under Subáthu on the south-west, a much greater thickness is found of the brown and olive clays and thin limestone of the Subáthu group. A still greater thickness of these purely nummulitic beds occurs in the sections along the south margin of the outlier, just inside the main boundary. These facts seem to indicate that there was here

some approach to a margin of the nummulitic sea, the features of which (whether shore or sea bottom) must have consisted of steeply scarped flat masses of horizontal palæozoic strata. A reasonable objection to the introduction of any actual shore here may be found in the total absence of anything like a shore deposit along so steep a coast-line. Even small pebbles are very rare in the Sirmúr series at any point, and the Subáthu group is almost exclusively made up of very fine mud, the calcareous element being quite subordinate in it throughout the Sub-Himalayan region.

Limits of the Sirmur area.—The lower tertiaries of the Sirmúr area do not quite form an outlier, as they are not completely cut off from the Sub-Himalayan zone. A narrow band of Subáthu beds, less than a quarter of a mile wide, crossing the Sutlej at Dihar, connects the Sirmúr area on the north-west with the innermost Sub-Himalayan zone of the Kángra area, where the nummulitic group soon disappears altogether, and is covered by higher beds. To the south-east the Sirmúr rocks have undergone the very opposite effect: owing to a general elevation in that direction, the counterpart of the depression to the north-west, they have been altogether removed by denudation; the bottom beds are the last left, high on the ridge, about 10 miles east by north from Náhan. The south boundary of this area is an exceedingly regular and well-marked feature, an abrupt junction with the younger tertiary formations. The nature of this boundary will form an important subject of discussion in connexion with these latter rocks. The inner boundary of the Sirmúrs in the Simla region is different from any other connected with the Sub-Himalayan rocks: at a few places, as along the south-easterly spur from the Bój mountain, the sandstones and clays of the middle horizon occur abutting steeply against the slates; but for the most part the junction is found in low ground, with the Subáthu clays at the contact, almost always steep and much crushed; and straggling extensions from the main area of the Subáthu group can be followed amongst the old rocks, as, for instance, the band passing north of Subáthu nearly up to Solan, between the Bój and the Król. Several small outliers of bottom Subáthu beds have also been observed, folded up in the slates, as may be seen on the old Simla road, above the Haripur rest-house, close to an outcrop of the Blaini limestone. Over the whole of this area, the massive Król limestone, and a great thickness of the underlying slates, must have been denuded before the deposition of the Subáthu group.

Easternmost outlier of the nummulitic group.—This is the fittest place to mention the one small outlier of the Subáthu group that

has been observed east of the Sirmúr area. A small patch of brown nummulitic clay occurs near the village of Bón, in a depression of the ridge of slates at the east end of the Dehra dún over Rikikés. The outlier is quite isolated, and some miles north of the Lower Himalayan boundary. As this ground, east of the Ganges, has been little examined, it is not unlikely that other such remnants may yet be found there; but any large area of these rocks, west of Nepál, would probably have been brought to notice.

It is thus still an open question, whether the nummulitic formation ever extended continuously along the southern face of the Himalayas, for no vestige of it has been found in the Sub-Himalayan zone of the middle region. The fact that the nearest known rocks of eocene age, at the west end of the Assam range, in the Gáro hills, are made up exclusively of fine clays, precisely like those of Subáthu, need only suggest similarity of origin. In both positions there is a marked absence of purely marine deposits; while in both cases these are introduced extensively away from the middle region, to the north-west beyond the Jhelum, and to the east in the Khási hills. The Assam range is, indeed, outside the Himalayan border, but this border, as we know it, has been in great measure defined in post-nummulitic times. It was, however, approximately fixed, as now, in earliest Siwalik (Náhan) times. Such a change of feature implies a great break between the deposits preceding and succeeding it; and this is a suggested measure of the possible separation of the Sirmúr and Siwalik series in the Simla region and throughout the middle Himalayas.

SIWALIK SERIES: NAHAN AREA.—It was in this Náhan area that by far the greater part of the original collections of Siwalik fossils were made, on which account alone this ground must be considered classical. It was here, too, that the study of these formations was first taken up by the Survey; and it so happens that the sections are peculiarly favourable for observation; or at least, features are here exposed that have not as yet been observed elsewhere, and that certainly are generally concealed. This exceptional character might indeed be reasonably taken as an objection to considering this ground as a standard of interpretation for any larger region; however this may be, it is certain that the facts here exposed give us the means of stating, in the clearest manner, one important condition of this question of interpretation, upon which the truth of our history of this mountain region must depend.

The area thus peculiarly circumstanced, in the neighbourhood of Náhan, does not at all correspond in length with the adjoining Sirmúr

area. The latter extends to the Sutlej; whereas, in the Sub-Himalayan zone, the features of the western region begin where the boundary of the Lower Himalayas first trends northwards, near Kálka. Just east of this point the width of the Sub-Himalayan zone is at its lowest. The lower Himalayas themselves are here somewhat protuberant southwards; but there is no exceptional compression of the upper tertiary rocks; the corresponding reduction in width of the fringing tertiary zone is effected by the absence of any trace of a dún. From the west end of the Kaiárda dún, which is the trans-Jumna continuation of the Dehra dún, to the east end of the Pinjor dún, which is the cis-Sutlej continuation of the Una dún, the outer Siwalik hills are confluent, for a length of nearly 30 miles, with those on the north of the Pinjor and Kaiárda dúns; so that the junction of the rocks forming these distinct ranges can be closely followed for that distance. It was from the examination of this junction that a clear separation was proposed between a Siwalik and a Náhan group. It is not yet proven that such a separation is not maintained eastwards, throughout the middle Himalayan region; but it certainly is not distinguishable on the extension to the north-west: and so, a compromise has been adopted—to speak of the inner or Náhan zone, and its representative rocks elsewhere, as Lower Siwaliks.

The Náhan, or Lower Siwalik rocks, forming the inner Sub-Himalayan zone at Náhan, consist mainly of massive grey sandstone, often spoken of as the lignite sandstone, from its frequently containing small nests and strings of fossil wood, which from early times till now have given rise to many sanguine reports of the discovery of coal. In deeper sections red or purple clays occur, associated with thinner, harder, darker sandstones, very like the rock of the Dagshai group. Owing to the contorted and faulted condition of these rocks, and the rugged, covered nature of the ground, accurate estimates of thickness are not easily made: from 2,000 to 5,000 feet may be taken as limits.

The rocks forming the outer tertiary zone, the true Siwalik hills, south of Náhan, consist at top of conglomerates and brown clays associated in very variable proportion, overlying a series of alternating thick, soft grey sandstones, and red and yellow clays. The total thickness may vary from 3,000 to 5,000 feet. In other ground the conglomeratic beds by themselves are at least 5,000 feet thick, with a similar thickness of grey sandstone between them and the Náhan horizon. These beds of the Siwalik hills proper will be distinguished—the conglomerates as Upper, and the sandstones and clays as Middle Siwaliks; even if the separation should not be maintained by fossil evidence, the stratigraphical distinction will be always necessary.

The Nahan-Siwalik boundary.—The junction of the Siwalik and Náhan groups is first described, because it clearly exhibits important characters that will be less confidently appealed to in the case of other boundaries. The topmost beds (conglomerates and clays) of the great series of deposits forming the outer hills, dip steadily towards the base of the higher hills, formed of massive sandstones and subordinate red clays of the Náhan zone. The strike in both rocks is the same, but the dip is generally higher on the inner side. Where the Márkanda crosses the boundary under Náhan, the general effect is well seen, and it closely resembles a continuous ascending section; so much so that the early discoverers of the Siwalik fossils accepted it as such, taking the inner beds to be the newer.

Upon a first recognition of the outer rocks as the newer, the immediate conjecture would be that of a fault; it is the explanation usually applied to junctions such as this. The dips might first suggest a doubt, for they certainly are not such as would, under ordinary conditions, result in connection with faulting. Further examination raises other doubts: the conglomerates of the outer beds are largely made up of stones very like that of the rock forming the contiguous hills, which at once suggests a break other than by faulting. Again, if the feature is due to a fault, it must be one of great throw, but the outline of the boundary, as traced through the hills, exhibits great and sudden irregularities, such as are almost incompatible with a great master-dislocation. One other test remains—that of the actual contact, which it is so rare to find exposed to observation: at a short distance to the east of the Márkanda, and close to where the first symptoms appear of the beginning of the Kaiárda dún, a clear section of the contact was found in a gully at the base of the inner hills, shewing the tilted Siwalik conglomerates abutting against a steep weathered surface of the older sandstones, proving that at this point any faulting whatever is out of the question.[1]

This is quite a crucial section, and until it is disposed of, it must take a ruling part in our consideration of this great boundary question. In any civilised, or even more accessible, country so critical an observation would have been examined by many experts since it was first noticed. That this has not been done is only an extra reason for laying stress upon the point. A conjecture has been offered (by Mr. Theobald) that the newer beds at the contact here are not true Siwaliks, but the same as some beds at the top of the series in the Siwalik hills east of the Jumna, and differing somewhat from the usual type of the

[1] Mem. G. S. I., III., Pt. 2, p. 108.

Siwalik conglomerates. This hint is worthy of notice, but it scarcely affects the question at issue, for the beds indicated, whether we choose to call them Siwalik or not, must be closely related to that series, as being at least apparently conformable to it, and having undergone the same disturbances, and must be totally distinct from any deposits formed subsequently to the elevation of the outer range.[1] Thus we may say that, for this portion of the ground, all the evidence, with one exception, suggests that this boundary is not due to faulting. The exception is the reversed lie of the plane of contact; and it is evident that this condition might be produced by lateral pressure upon an originally normal face of deposition.

Another important point in the discussion of this boundary is, that no satisfactory identification has been made between beds on opposite sides of it in this section at Náhan. If this should be correct, that in the great thickness of rocks outside this boundary none of the inner rocks are represented, the consequences that follow upon either interpretation of the junction are rather startling: if it be a fault, the throw must amount to several thousand feet; and, if it be an original boundary, disturbance of Sub-Himalayan (Siwalik) rocks, with denudation to a prodigious extent, must have taken place within the Sub-Himalayan (Siwalik) period, involving great unconformity here between the upper and lower groups. A compromise may be yet made out; but any possible identification of the beds of the inner zone, in the rock-series of the outer zone, must be low down in this latter series, and so would still leave a large break to be accounted for by the fault or the unconformity, as may be ultimately decided. It should be remembered that in such rapidly forming diluvial deposits as those of the Siwalik formation, very great discrepancies might occur between synchronous beds within short distances, so that great judgment and a full consideration of many circumstances are needed in deciding this question. An explanation of this peculiar unconformity will be suggested in describing its disappearance westward, in the Kángra region.

The most westerly point at which the peculiar Náhan-Siwalik junction has been observed is in the Sursulla, below Kálka, where the

[1] Because of doubts expressed regarding this section, although no one, that I know of, has examined the spot indicated, I have wished much for an opportunity to re-visit it. Such an occasion, after a lapse of 18 years, has occurred within the last three months, since the above remarks were written. The position lies on the path to Khairwála from the Rajah's garden on the Márkanda, near the village of Tib. I was disappointed to find that no section of the contact is now exposed, but on this point I never had any doubts of the accuracy of my original observation. I have, however, satisfied myself again that the outer rocks at the contact are the regular Upper Siwalik strata.—H. B. M.

massive horizontal Upper Siwalik conglomerate, forming the surface of the Pinjor dún, takes a strong dip towards its junction with the highly inclined sandstones of the inner zone. Beyond this no contact-section of the Upper Siwaliks has been observed on the north side of the dún for more than 50 miles, to near the Sutlej, where everything is changed, and the conglomerates are nearly vertical, having a slight south-westerly underlie, and are thus in apparent continuous sequence with hard Lower Siwalik rocks forming the ridge of the inner zone. This Sutlej section belongs to the Kángra area.

The continuation to the east is more doubtful: at this end of the exposed contact in the Náhan hills, the tilted conglomerates at the boundary pass on to form the crest of the range on the south side of the Kaiárda dún, and flatten out to form its floor; but no near sections of the junction with the rocks of the Náhan zone are visible.

The Nahan-Sirmur boundary.—Within the Náhan area the junction of the Siwalik and Sirmúr series corresponds with what we shall constantly refer to as the *main boundary;* for we may fairly give this name to the most persistent and striking structural feature of the whole mountain region—the abrupt junction of the slaty or schistose rocks of the mountains with the rocks of the Sub-Himalayan zone. The correct interpretation of this line of junction is a first step towards understanding the history of the mountains. The scarcely disputed admission, that the Sub-Himalayan deposits are in great part made up of Himalayan debris, is at least suggestive that the present boundary may have had something to do with the original one; but the closer inspection of the feature seems always to deter from any further encouragement of this view: the appearance is nearly always that of a reversed fault, the outcrop of the plane of junction in the bottom of the valley being generally inside a line connecting the outcrops of the same plane on the adjacent spurs; and consequently this plane of junction between tertiary and Himalayan beds is inclined towards the mountains. It is only through the Sirmúr rocks in the Simla region that we can bring any direct argument to bear upon this question. Elsewhere there are no terms of comparison between the rocks on opposite sides of this sharp line; whereas here the beds on either side unquestionably belong to the same great tertiary series. We have seen that the upper Sirmúr beds themselves exhibit strongly the type of the Sub-Himalayan deposits, and are also presumably derived from the same source—denudation of the Himalayan area.

The question again turns upon the part taken by faulting. If this main boundary is a *post*-Siwalik fault, we might expect to be able to identify some of the beds on opposite sides. The conditions are

altogether favourable for such a recognition: the highest beds on the upthrow side are sufficiently distinctive, and the beds on the down-throw side are thoroughly turned up and eroded; yet there is no approach to a resemblance; on the contrary, clays become more and more frequent as we get deep in the Lower Siwalik (Náhan) group, and we have seen that the top beds of the Sirmúrs are exclusively sandstone. No trace of the very distinctive nummulitic clays has ever been seen south of the junction, or as fault-rock in the supposed faulted boundary.

These arguments may, of course, be met by magnifying the throw of the supposed fault, so that the Sirmúr rocks should be completely buried out of sight to the south: or a more plausible objection might be raised, that as the outcrops we bring into comparison are for the most part at a considerable distance from the fault, and at a still greater distance from each other, the correspondence cannot be expected; for theoretically, the agreement demanded only holds exactly for the beds originally continuous across the dislocation. It might thus be suggested that the plant-bearing sandstones of Kasauli belong to the same horizon as the Lower Siwalik clays, or the lignite sandstone. Those who have examined the rocks are least disposed to adopt this supposition; and unless one or other of these views is adopted, the argument is binding in favour of this main boundary being an original line of junction, however modified by the subsequent compression to which even the Upper Siwaliks have been subjected.

This conclusion would establish for the middle Himalayan region a very great unconformable break between the upper and lower tertiaries—the Siwalik and the Sirmúr series. It would shew that a great elevation took place, with deep erosion, along the margin of the Lower Himalayan region, in the interval between these formations.

In the case of the Náhan-Siwalik boundary in the Simla region another argument, besides that founded on the contrast of the strata on opposite sides of the junction, was used to shew that the present boundary coincided with the original margin of deposition, and was not a line of fault. This argument was, the very broken direction of the boundary-line. Similar observations apply to the main boundary: the Dehra dún occupies a great bay in the Lower Himalayan area, so that a line joining the termination of the Sirmúr beds in Sirmúr to the small outlier of the same beds east of the Ganges, would touch the Siwalik range south of Dehra; and within this bay the main boundary exhibits several sharp bends, not traceable to cross-faults. Such twists would be scarcely compatible with a great dislocation having several thousand feet of throw, as this boundary must have, if it is to be regarded as a post-Siwalik fault.

THE JUMNA-GANGES AREA.—Although few of the Siwalik fossils were obtained east of the Jumna, it was here the name took its origin, as adopted by Colonel Cautley from *Shib-wála*, the native name for the range separating the Dehra dún from the plains. A more typical Siwalik range could not have been chosen. The axis of the normal anticlinal flexure runs close along the outer edge of the ridge, the beds to the south of the anticlinal having been much denuded, except at the end near the Ganges, where there is a pretty full remnant of the steep southerly dipping beds, gradually becoming vertical in the conglomerates of the little hills west of Hardwár.

Composition in relation to the great rivers.—By comparing this range with its representative in the adjoining region to the west, we find an illustration of the fact already mentioned,—how the Siwalik deposits vary according to their position relatively to the great rivers. The contrast between the rocks of the outer range on opposite sides of the Jumna is so great, that it has been doubted if they can be equivalent; to the west, throughout the Náhan area, clays enter largely into the section, and the conglomerates are made up of the debris of the rocks forming the higher hills immediately to the north, principally the sandstone of the Náhan and the Sirmúr groups; whereas in the range between the Ganges and Jumna, clays are very subordinate, and the conglomerates are composed of the hardest quartzite pebbles, just like the shingle now found in the great mountain torrents. This portion of the range is, in fact, an ancient diluvial fan of the rivers Tons, Jumna, and Ganges. The Jumna, after its confluence with the Tons, now flows very obliquely across the dún, and passes through the outer range far to the west of the point, where it leaves the high mountains, having had to double round the immense accumulation of hard materials it had formerly laid down in front of that gorge. The passes of both the Jumna and Ganges in the Siwalik range are now strongly marked by cross-fractures of the rocks, with contrasting dips on opposite sides; but it is more likely that the rivers helped to determine the position of these fractures, than the reverse; for the rivers have not ceased to flow here since pre-Siwalik times: when the first elevation set in, the rivers had to take to channels of erosion; and when the fracturing forces took effect, these lines of erosion were the positions of least resistance.

Identification of beds in the two zones.—The identification made by Colonel Cautley[1] of certain beds at the south base of the cis-Jumna[2]

[1] Trans. Geol. Soc., London, 2nd Series, Vol. V, p. 271; J. A. S., B, 1834, Vol. III, 528.

[2] The prefixes *cis* and *trans* are used in Upper India with reference to the older British possessions in Eastern India. Cis-Jumna consequently means east of Jumna; trans-Jumna, west.

range with some beds of the inner zone at Náhan is well worth attention. Taking the Náhan beds, by reason of their apparent position, as the highest in that section, he accounted for the non-appearance east of the Jumna of the more fossiliferous strata of the west, by the smaller upheaval in the former position. As already explained, the reverse is the case; and the beds in question, in which fossils were found, at the entrance to the Kálawála pass (cis-Jumna), the same as in the Náhan beds, are probably older than any in the outer range trans-Jumna. A closer search might detect the suspected unconformity between these beds at the south end of Kálawála pass and the overlying Siwalik sandstones. The greater abundance of fossils in the range trans-Jumna than cis-Jumna may easily be due to the contrasting nature of the deposits.

Suggested connection of the two zones in this area.—The complete confirmation of the identification mentioned in the last paragraph, need not disturb the view given of the equivalence of the outer ranges on opposite sides of the Jumna; but this equivalence has been questioned. Throughout the dún east of Dehra there is no representative of the Náhan range, any remnant of these rocks being covered by a great bank of detritus; but in the western dún this inner ridge of the Sub-Himalayas is well defined, and in the Nún, under Mansúri (Mussooree), there is a peculiarly puzzling section. The stream, as usual, has cut a steep narrow gorge through the flanking ridge of the massive lignite sandstone, here nearly vertical, but with a slight inward underlie; and just below the gorge there is in the low banks a nearly continuous section of seemingly conformable beds, in which the sandstone becomes pebbly, and gradually alternates with strong beds of conglomerate, the northerly underlie being steady throughout. According to the universal order in all normal sections, conglomerates always increase in the upper beds, so this section in the Nún must be an inverted series, and it most resembles that in the range south of the dún.

If this link should be confirmed, we should have to recast the view sketched above regarding the relations of the cis- and trans-Jumna Siwaliks; for there is every reason to suppose that the massive sandstone of the Nún is the same as that of Náhan, with which it may be said to be continuous. There would then be much plausibility in the view once advocated by Mr. Theobald (in an unpublished report), that the original Siwalik hills are chiefly composed of Náhan rocks, and that the more fossiliferous and newer trans-Jumna Siwaliks are not represented to the east of the river, having been denuded away, or else never upheaved.

The alternative interpretations, to reconcile the Nún section with the current opinion of the equivalence of the outer Siwaliks on both

sides of the Jumna, would be—to suppose that the Nún conglomerates are true top beds of the Náhan group, and quite different from those of the outer range; or else, to suppose a break, by a concealed fault, in the apparently regular sequence between them and the lignite sandstone. The question must be worked out on the ground: though it is needful to point it out, it would be out of place to discuss it further in these pages.[1]

THE GAHRWAL AND KUMAUN AREA.—These hill districts correspond with the Rohilkand division of the plains, between the Ganges and the Nepál frontier. This ground has scarcely been looked at. Within ten miles east of the Ganges the Siwalik rocks proper are well represented, and a narrow belt of Náhan beds separates them from the slaty rocks of the Lower Himalayan mountains. Further east, the outer range, and the rocks forming it, seem to be generally absent; and the inner hills, formed of the massive sandstones supposed to belong to the lower Siwalik or Náhan group, become very prominent. The steady north-easterly dip prevails, wherever observations have been made. In General Strachey's paper on this part of the Himalayas[2] a very important observation is recorded, that the trap-rock of the Lower Himalayas enters the sandstone of the Sub-Himalayan zone. The position is in the Gola river south of Bhimtál. No fact of the kind has been noticed elsewhere.

Operations have been undertaken to smelt iron on a large scale from an ore concentrated in the red clays at the base of these hills under Naini Tal. Similar ferriferous clay is known to occur near Náhan, and again in the same rocks far to the east in Sikkim.

NEPÁL AREA[3].—For a length of 500 miles the kingdom of Nepál completely arrests all study of Himalayan geology, with the exception of the single track to Kathmándu (Katmandoo), and a small area around the valley. On this track very complete representatives are found of the two Sub-Himalayan ranges and their intervening dún or *mári*, as the valley is called here. The Chúriagháti range is structurally a *facsimile* of the original Siwaliks. At the outer base, at Bichiako, there are some earthy rusty beds, all greatly crushed. The dip soon settles down to 30° to north-north-west, maintaining the same angle steadily to the top of the pass.

[1] Salt-pans were once set up on a small scale in the gorge of the Nún: it is not known whether this enterprise was started on the strength of the name *nún* (salt), or on account of the efflorescence that is often locally abundant on exposed surfaces of the lignite sandstone, or on the trust of some tradition of the occurrence of rock-salt.

[2] Q. J. G. S., L, 1851, Vol. VII, p. 296.

[3] Rec. G. S. I., 1875, VIII, p. 93.

This is the typical structure of these detached Sub-Himalayan ranges, the flat inner half of a normal anticlinal flexure. The range is about four miles wide, which would give an aggregate thickness of about 10,000 feet of rock. The pass, as is universal in these ranges, follows the broad bed of a torrent to near the summit, where the road turns up a steep gully, partly artificial.

The lower half of the section is sand, and the upper half conglomerate. In the Siwaliks of the North-West the passage between these two rocks is gradual and alternating; in the Chúriagháti section it was noticed that the change is rapid and complete, from an almost unbroken mass of fine grey sand to an equally uniform mass of pale yellowish-brown conglomerate. This may not be a point of any importance; but special notice was made of the exceedingly fresh aspect of these deposits as compared with the rocks of the original Siwalik range,—a point that may have some meaning in connexion with Mr. Theobald's suggestion, already mentioned, that the latter rocks may belong to the Náhan horizon. In this respect the rocks of the Chúriagháti range more resemble those of the outermost hills of the trans-Jumna region.

This same newness of aspect may be noticed in comparing the Chúriagháti rocks with those of the inner Sub-Himalayan range on the north side of the dún at Etaunda (the rest-house on the road to Kathmándu), in order to represent the apparent impossibility of the two ranges being a repetition of the same rock-series; and hence the presumption that their junction is not a fault. In the Rápti, immediately under Etounda, there are outcrops of the rusty sandy clays and greenish-grey hard sandstone at the base of the section to the north. They dip at 60° to north by east. Wherever observed along the road, this dip (with slight variation in amount) was found constant, and there is but little change in the character of the rock. Clays occur, but very subordinately; the sandstone becomes somewhat softer in the higher beds, and there are here several layers of thin conglomerates. It is clearly a normal ascending section, and in no particular is there any near resemblance to the series of the outer range. The section here is about two miles wide, which would give a thickness of about 10,000 feet, there being nothing to suggest repetition by faulting or flexure. As usual, the contact with the rocks of the mountain is concealed.

Regarding the interpretation of this section: we might explain the actual difference of composition by the presumable difference in successive zones of one great belt of torrential deposits, and the actual differences of

texture by the presumable greater induration of the inner band, and thus make out that the two rock-series were originally continuous and equivalent, and that their present relation must be due to a great fault. The impression made on the observer was decidedly against that equivalence; and hence, that the present relative position is, like that in the Náhan section, to a great extent aboriginal.

Sikkim and Bhútán areas.[1]—Throughout the Sikkim and Bhútán Duárs there is no representative of the Siwalik hills (the outer zone of the Sub-Himalayas); and in two places the Sub-Himalayan rocks are altogether absent, or concealed.[2] One of these gaps, about 10 miles wide, is just south of Dáling Fort, and corresponds to a marked promontory of the older rocks of the mountains. The other gap is much longer, from the Jaldoka to beyond the Tursa, a distance of 40 miles, and throughout this area also the base of the mountains is prominent and irregular. It seems probable (see p. 522) that the absence of the tertiary sandstones in this ground is due to their partial removal, and the complete concealment of the denuded outcrops by the great gravel deposits that are here accumulated at the foot of the hills. There is nothing in the old rocks to suggest their former greater extension in this position: the Damúda rocks also are absent, but here, as elsewhere, the same belt of slaty formations separates the gneissic rocks from the plains.

In close proximity to these gaps, the hills and rocks of the inner Sub-Himalayan zone are in full force, shewing no tendency to thin out towards those blank areas. In the Máhánadi the thickness is estimated by Mr. Mallet as 11,000 feet, and the characters are the same as noticed elsewhere; soft massive grey sandstone being the prevailing rock, with occasional clunchy clays, especially towards the base, where these are sometimes highly ferruginous. Nests of poor lignite, and even small broken seams, occur in the sandstones. The upper beds are often conglomeratic, sometimes coarsely so. In all there is a prevailing dip towards the mountains, so the highest beds occur next the main boundary, but no actual contact-section of this feature has been described. It is clear, however, that whatever explanation of it can be made out elsewhere will apply here also.

Upper Assam area.—To the east of Bhútán the Himalayas north of the Assam valley are occupied by various tribes of savages, and the only observations worth mentioning of that ground are those made by

[1] Mallet: Mem. G. S. I., 1874, XI, p. 45.
[2] First noticed by Colonel Godwin-Austen, J. A. S. B., XXXVII, p. 117.

Colonel Godwin-Austen[1] in the Daphla hills of the Dikráng basin, adjoining the Darrang and Lakhimpur districts of Upper Assam. Here again there are two well-marked ranges of Sub-Himalayan hills, with an intervening dún. Each range is formed of a normal anticlinal flexure, directed from the mountains,[2] just as at the base of the North-Western Himalayas; and the inner range is, at least in great part, formed of older beds than the outer one. Here, too, nests of lignite are of frequent occurrence in the sandstone.

The same lignite sandstones have been observed more to the east, north of Dibrugarh, with the usual high northerly dip.[3]

[1] J. A. S. B. 1875, XLIV, p. 35.

[2] *i. e.*, having the axis-plane sloping towards the mountains (see note, p. 528).

[3] Mem. G. S. I., IV, p. 393.

CHAPTER XXIII.

EXTRA-PENINSULAR AREA.

SUB-HIMALAYAS—(*continued.*)

TERMINAL SUB-HIMALAYAS: THE KÁNGRA AREA — General structure — The Ghambar-Basauli fault — The Kosari and Badsar-Nurpúr faults — Extinction of the Náhan-Siwalik boundary — The Sutlej at Bubhór — Local extinction of the Náhan-Sirmúr boundary — Difficulties of classification in the Kángra area — Bubhór and Beláspur sections compared — Doubtful beds in the Sirmúr zone — Want of fossils — The base of the Dhauladhár — North-western termination of the Kángra area — The Mandi rock-salt. THE JAMU AREA — Boundaries — Special feature — Sirmúr zone at the Rávi — Western expansion of the Sirmúr zone — Inliers — Characters of the Subáthu group — Tertiary-palæozoic relation — Comparison with sections of the Simla region — Doubtful newer rocks of the Sirmúr zone — Other general features of the Sirmúr zone — Sirmúr-Siwalik boundary — The Basauli-Naushera fault — Riássi conglomerates — The outer Siwalik zone. SUMMARY.

TERMINAL SUB-HIMALAYAS: **Kangra area.**—In the last chapter the Sub-Himalayan rocks were traced from the typical Simla area to their eastern extension in Assam; we have now to return to the North-West Himalayas and examine the sections to the west of the Simla region.[1] The great and rapid expansion of the tertiary zone to the north-west corresponds with the extinction of the Lower Himalayan region. From about half-way between Náhan and Kálka the "main boundary" bends steadily inwards, and continues this northerly course for nearly 80 miles, to the base of the Dhauladhár ridge, which is directly on the prolongation of the main snowy range of the middle Himalayas. The Sub-Himalayan ranges are for the most part unaffected by this bend of the main boundary; and thus the ground on the prolongation of the Lower Himalayas is occupied by tertiary rocks, 60 miles wide inside Hoshiárpur. The greater part of this area, up to the Rávi, is in the Kángra district; but this geological field, designated as the Kángra area, must be understood to begin east of the Sutlej,

[1] It would be impossible to give any idea of the structure of this ground without mentioning features and localities that are not indicated on the small map accompanying this work: it will therefore be difficult to follow these descriptions without reference to a larger map (see note, p. 560).

about the east end of the Pinjor (or Kálka) dún. The Sutlej and the Biás flow westwards, across the terminal boundary of the Lower Himalayas, and traverse the dúns and ridges of the Kángra area in very zig-zag courses.

General structure.—The outer Siwalik range of the Kángra area is continuous with that of the Náhan area; so it will appear that the great spread of tertiary rocks to the north-west takes place for the most part on the prolongation of the Náhan, or inner Sub-Himalayan, zone of the middle Himalayan region. Both boundaries of this zone, as lines of contact of dissimilar rocks, change in character and disappear; and in the middle of the expanded zone new features supervene, flexures and great faults, unlike anything as yet observed in the ground to the east.

A more peculiar feature of the terminal Sub-Himalayas is the introduction of an inner zone of oldest tertiaries, not represented at all in the middle Himalayas, but on the prolongation of, and actually continuous with, the Sirmúr series, on the margin of the Lower Himalayas in the Simla region. The Sutlej may be given as the point where the Sirmúr rocks take their place as belonging to the Sub-Himalayas; and a great change rapidly supervenes in the aspect of all the rock-features. In all the zones the introduction of apparently higher beds to the north-west is the rule.

It has been already observed that our representation of the Sub-Himalayan series depends mainly upon the interpretation put upon certain leading structural features peculiar to such mountain regions, and which are markedly homologous in all the formations; our attention must therefore be principally turned upon those features; and as their characters are perhaps best exhibited in their less extreme form, among the newer rocks, the rule observed in this work, to proceed from the oldest to the newest, cannot be followed.

The Ghambar-Basauli fault.—At the east end of the Pinjor dún, in the section of the Mangrad, south-south-east of Kálka, the Náhan zone is scarcely a quarter of a mile wide; the strata are vertical, and all of the lower type noticed in the Náhan section, hard purplish sandstones and red clays. North-north-west of Kálka, rocks of this stamp, in a very contorted condition, form a confused congeries of hills in the Mailog and Nálagarh States. About Khadi, close to the main boundary, on the Subáthu and Budi road, higher beds occur, paler, softer, coarser sandstones; and there is the beginning of a distinct feature, a faulted synclinal flexure, diverging steadily from the main boundary to the north-west. In this direction the character of the

dislocation becomes rapidly developed, and in the valley of the Ghambar it is perfectly defined as a great fault, thick conglomeratic sandstones dipping steeply to the north-east towards, or under, deep red clays and hard sandstones. It follows a remarkably straight course across the Sutlej, through the Kángra district, to Basauli on the Rávi, and thence to Riássi on the Chináb, where it again joins the outer Sirmúr boundary, after a course of nearly 200 miles. It is well seen at many places, as in the Banganga river near the main road to Kángra; about Kotleh on the Bhágsu-Nurpúr road, and at Basauli on the Rávi. The actual contact is always disguised, but there can scarcely be a doubt that it is a great fault, of the reversed order that is most usual in these mountain sections: the strata on opposite sides are nearly parallel to each other, the upthrow is persistently on the inner side, and so the newer rocks in normal order (*i. e.*, not inverted) actually underlie the older; as if in a double folded flexure the upper side of the anticlinal had subsided on, or been pushed over, the lower side of the synclinal limb, the contortion itself having been removed by denudation.

At Juálamuki on this line of fissure there is a temple built in which flames issue continuously from the ground round the base of the idol. At Lunsu, under Dalhousie, there is a mineral spring on this same line of dislocation.

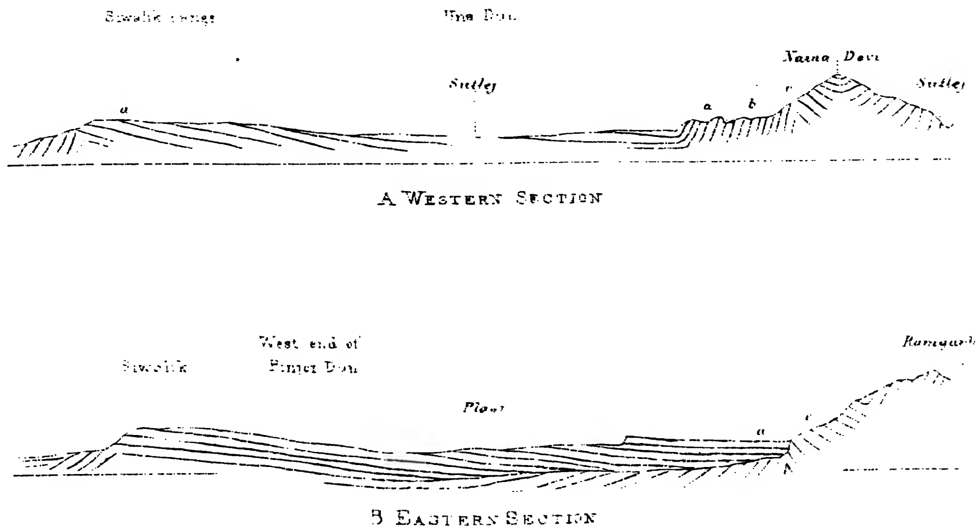
The Kosari and Badsar-Nurpur faults. — South of the Ghambar, the complex range of the Nálagarh hills continues up to the Sutlej, where two lines of dislocation take their rise and result in steady, well-defined ridges to the north-west. The southernmost of these lines is known as the Kosari fault, from a village on the bank of the Sutlej at the north end of the Bubhór gorge; it is comparatively a minor feature, running down the centre of the compacted group of ridges into which the Parwain range is divided on the south-east. The Badsar fault, called after a village 20 miles from the Sutlej, at the north base of this same range of hills, is a principal structural feature of the trans-Sutlej Sub-Himalayas, being continuous for 300 miles up to and beyond the Jhelum. It clearly originates in an anticlinal flexure, and is again recognisable as such at several points of its course, as at Nurpúr; sometimes the dislocation is small, but, as a rule, there is much faulting; and towards the Sutlej the downthrow is on the north side. The Nadaun dún lies in a trough between the Badsar and Ghambar faults.

These great lines of dislocation determine the chief features of the upper tertiary zone of the North-West; and we have seen that they are quite unconnected with any feature of the tertiary zone of the middle

Himalayas. With the introduction of these new features, characteristic of the north-western region, the two chief structural features of the Sub-Himalayas in the middle region—the Náhan-Siwalik and Náhan-Sirmúr boundaries—become extinct. These boundaries have already been interpreted as primarily unconformities, marking decided divisions in the tertiary series; and thus we already find established, in the middle of the Kángra area, the difficulty to be confronted throughout the tertiary series of the North-West, the absence of any well-marked stratigraphical horizons.

Extinction of the Nahan-Siwalik boundary.—This boundary, as described to the east (p. 537), with top Siwaliks abutting at various angles against crushed Náhan beds along a very zig-zag line of junction, continues all along the Pinjor dún to beyond Nálagarh, 16 miles north-east of Rupár (Roopur), where lofty terraces of brown Siwalik clays lie flatly close up to the ridge of crushed red Náhan rocks. Seen in such juxtaposition as this, the possibility of a conformable transition between the two would appear out of the question; yet such is apparently the case within 15 miles to the north-west. North of Anandpur, low flanking hills, formed of these same upper Siwalik strata, turned up and vertical, rise in front of the ridge of the red rocks. A section is recorded just north of Nanowal (close to Anandpur), where the very strata forming the dún turn up, within a space of 100 yards, from being horizontal to a dip of 80° to south-west; in the section to the north they pass down into the grey rocks of the middle Siwaliks. On this section, under Naina Devi peak, there is still an abrupt, probably faulted, contact of the grey and the red rocks, all being parallel and vertical; but on the continuation of the same strike, where the Sutlej cuts a deep gorge through the ridge, and the section is fully exposed, it is impossible to draw a line between the two types of rock. Within 10 miles farther to the north-west any semblance of a continuation of the original Náhan-Siwalik boundary is lost; the dip flattens, and the Naina Devi ridge, as defined by a core of the harder rocks, disappears, all the strata rolling over round the end of the ridge.

In the annexed figures an attempt is made to illustrate the interpretation put upon the observed facts. Throughout the western region superficial features of the same character as those on section B, between *a* and *c*, are interpreted as great faults; where beds several thousand feet apart in geological position are found in abrupt contact. The reasons for taking such a totally different view of like features in the eastern sections are: 1st, that the horizontal features (the outlines in plan) of the junction are strikingly different; in the west they observe a



Diagrammatic Sections (10 Miles apart) showing relations of Siwalik Series east and west of the Sutlej

a Upper Siwalik b Middle Siwalik c Lower Siwalik (Nahan).

Scale Horizontal 1 Inch = 4 Miles : Vertical 1 Inch = 8000 feet.

straight or very flatly curved course throughout great distances, while in the Simla region the Náhan-Siwalik boundary is extremely and sharply irregular in direction; and 2ndly, one section of the actual contact was observed here, giving independent and absolute evidence against faulting in that position. The reading to be taken from these sections is, that the disturbance began earlier, or progressed much more rapidly, in the east, and took effect as elevation over a broader area, entailing a greater denudation of the lower group along the axis and in its neighbourhood; while in the west the disturbance took effect as greater compression of the flexure and a more contracted elevation. In both cases deposition progressed continuously and conformably in the adjoining ground, and the latest accumulations gradually overlapped the denuded eastern area, producing extreme local unconformity along a narrow belt of outcrop, while the same beds in the western section became involved in the continued compression of the flexure at that point.

The Sutlej at Bubhor.—The explanation just given of the change in the Náhan-Siwalik boundary, and its disappearance westwards, may seem somewhat fanciful, involving extreme unconformity and continuous sequence of strata within a very narrow space; but we find in this very ground, in one of the sections compared (that of the Sutlej through the Naina Devi ridge at Bubhór), most remarkable independent proof of that slow, creeping action of the disturbing forces which is all that is required for the result claimed. The same facts will furnish a very striking instance of the statement already made regarding the composition of the Siwalik rocks in relation to the actual rivers, and the pre-Siwalik age of the segreat drainage channels.

The Upper Siwaliks at Bubhór are entirely formed of coarse conglomerates, just like the shingle in the river bed; and the grey middle Siwaliks are pebbly throughout, all being vertical as in the figured section A; while within 5 to 10 miles on either side of the river, common brown clays constitute the bulk of the upper group, conglomerates being quite subordinate. The same distribution of deposits is observable in the outer Siwalik range, the case being analogous to that already described for the Jumna and the Siwaliks of Dehra (p. 541). Instead of making a passage through the strong conglomerates opposite the gorge at Bubhór, the river has crept round by Rupár, where the strata forming the range are altogether clays. It seems impossible to avoid the inference, that the Siwalik conglomerates of Bubhór were formed when already the Sutlej had been fixed in its present position by a gorge in the axis of the Naina Devi ridge, formed of the tilted Náhan, or Lower Siwalik strata, which are still an apparent conformity with the said conglomerates.

This is not a conjectural inference, as in the case of the boundary, but one that scarcely admits of an alternative; as it would be more wonderful still to suppose that the river kept its position throughout all that disturbance, without any initial obligatory point in the neighbourhood above Bubhór. Besides, the deposits in question are such as are only found near the mouth of a torrential gorge. After that gorge was first marked out in the rising flexure of the Náhan strata, the river must have scattered its boulders and gravel over a wide space on either side; while at the same time the flexure was steadily encroaching, and so slowly as not to break the continuous parallelism of the series, the lowest bed of which may have been vertical before the highest was deposited. The required result can easily be imagined with the aid of the figured section, page 550: a greater concentration of the flexure would change the local overlap-unconformity in figure B into the apparent conformity of figure A.[1]

This conclusion as to the age of the Naina Devi ridge, the second (from the outside) of the Siwalik ranges on the Sutlej, must bear some weight in the discussion of the equivalence or otherwise of certain analogous or homologous deposits, external or internal to that range. But it must not be forgotten in this connexion, that this case of the Náhan-Siwalik boundary has suggested a longitudinal as well as a transverse progression in the disturbing action, so that analogous deposits on the same continuous zone need not be, or cannot be, strictly equivalent in time, any more than exactly similar deposits in the several successive homologous zones.

Extinction of the Nahan-Sirmur boundary.—The Náhan-Sirmúr boundary of the Simla region and of the Náhan area is one and the same as the main boundary of the middle Himalayas (p. 528)—the junction of the tertiary Sub-Himalayan formations with the old rocks of the higher mountains. The presence of the Sirmúr outlier on the Lower Himalayas of the Simla region does not alter this condition, which continues in force for some distance into the Kángra area. For a length of 20 miles near the Sutlej a ridge of old limestone, along this junction, separates the Sirmúr outlier from the Sub-Himalayan zone. Near Beláspur this ridge trends to east of north, and Sirmúr rocks take its place at the boundary, while the ridge crosses the Sutlej at Dihar; but just beyond the river it dies out in the midst of nummulitic clays.

The presence of the Sirmúr rocks, composed in their upper measures of distinctly Sub-Himalayan deposits, enabled us to discuss the nature of

[1] The necessary distortion of these sections, to make the lines visible, greatly reduces the verisimilitude of the features.

this main boundary, with the result that it is probably of pre-Náhan origin. Evidence to the same effect is found on the continuation of the boundary up to the Sutlej. Although the lower Siwalik (Náhan) rocks of the Mailog and Nálagarh hills are greatly disturbed and deeply eroded, no trace of the distinctive rocks of the contiguous Sirmúrs has been detected; on the contrary, we find here strong additional evidence of the asserted unconformity in the eastern region. Although clearly on the prolongation of the Náhan zone, the rocks of the Mailog hills do not closely resemble the corresponding rocks of the Náhan area; the massive lignite sandstone is not developed, red clays and hard sandstones prevail, like those at the base of the section at Náhan, and where higher beds occur, they are different from any seen to the east. They come in gradually along the main boundary, and are in force in the valley of the Gamrola and at the Sutlej. They consist principally of thick conglomeratic sandstones, and the debris is largely composed of Sirmúr rocks, including the Subáthu nummulitics. Thus it is clear that the older tertiaries were indurated and undergoing denudation at the time when these Gamrola conglomerates were deposited. Whether these latter are really of lower Siwalik age is a point upon which some remarks will be presently made.

The boundary continues in a very direct line nearly due north, for some 20 miles beyond the Sutlej, into the basin of the Biás. The contrasting characters are well displayed nearly to the end, soft grey conglomeratic sandstones dipping flatly eastwards, close up to dark red clays and hard purple sandstones of the Sirmúr zone, with a high dip in the same direction. At one spot, near Dubrog, a contact is obscurely seen: coarse conglomerates, here containing well-rounded boulders of quartzite and gneiss, 2 feet in diameter, shivered to splinters *in situ* by the crushing they had undergone, are found jumbled together with the red rocks, and not confined to a definite vertical band; the conglomerate occurs *in situ* at 100 yards east of an outcrop of the red rocks, indicating a steep overlap or a broken fault. Higher beds come in rapidly to the north, on the upthrow side, indicating the dying out of the dislocation; and at last the strata are continuous across the prolongation of "the main boundary" of the eastern region, so that here one can pass without any break from the Náhan zone into the Sirmúr zone; and the fresh-looking conglomeratic top beds of the former appear to be in regular sequence with the Sirmúr series.

The invasion of the Sirmúr zone by the rocks of the Náhan zone is not, however, complete. Another independent dislocation some 4 miles to the east takes the place of the extinct boundary, overlapping its end

and running to the north-west in a broad curve, parallel to the shore of the great bay of the tertiary formations, near the head of which the Biás issues from the mountains. After a run of about 40 miles this substitute dislocation ceases, and is again replaced near Barwárna (5 miles south of Pálampur) by an exterior line of boundary, on about the prolongation of the old main boundary. The recurrence of a similar feature on the same strike looks as if an early line of upheaval had been worn down and overlapped by later deposits; but this suggestion of the underground direct continuity of these equivalent boundaries on opposite sides of the Biás may be only imaginary. It is perhaps more likely that the peculiarly symmetrical arrangement of these structural lines near the Biás should be a necessary adaptation of the planes of fracture in the tertiary basin to the form of the compressing surface. From Barwárna the restored Náhan-Sirmúr boundary becomes again a very permanent feature, traceable continuously through the Jamu hills to near the Jhelum. To the north-west of the Sutlej, however, where the Sirmúr series takes its place in the Sub-Himalayan zone, this line of junction can no longer be styled the main boundary; this title must be reserved for the contact of the tertiary rocks with the old rocks of the mountains (p. 539); and although the hills of the Sirmúr zone have a very markedly greater elevation than those of the newer tertiary area, there is always a greater orographical contrast accompanying the change from the tertiaries to the old rocks.

Difficulties of classification in the Kangra area.—We have now lost sight of the features which enabled us to trace exact divisions in the tertiary series in the Náhan area. Even the great boundary which in the north-west, as in the Simla region, separates an inner zone of lower tertiary rocks, is partially obliterated in the neighbourhood of the Biás, where one can pass from conglomerates of Siwalik type down to nummulitic beds without apparent stratigraphical break. Unconnected with those boundaries we found in the Kángra area great persistent lines of separation, having more distinctly the stamp of dislocations. If one could frankly accept these lines as faults, pure and simple, in a completed series of deposits, such as can be represented in a diagram, the correlation of the strata would be an easy matter; for in each area so cut off, we find a sequence of deposits having a very decided general likeness, marked by harder, redder beds at the base, and by conglomeratic beds at top. Two considerations are, however, always present to sap one's confidence in such ready identifications. There is the condition of the almost incredibly slow creeping manner in which the features of disturbance were produced; so that, although we must accept these lines of dislocation as primarily fractures, there can be no certainty that the fault is of later

date than strata found disturbed in its immediate neighbourhood—that the conglomerates on the upthrow side of the Ghambar fault are not older than similar beds in unbroken sequence with fractured strata on the down-throw side. And from the other point of view it is to be remembered, that from late nummulitic times the conditions of deposition of these tertiary rocks have been very much alike—rain and river accumulations, on the margin, and from the debris, of the Himalayan region: so that a conglomerate of an early diluvial zone might be undistinguishable from a very much newer rock in an outer zone of the same geological field, and thus utterly stultify the *primâ facie* conclusion of their geological equivalence.

A couple of examples will illustrate the difficulty of any detailed delineation of equivalent stratigraphical horizons in the Sub-Himalayas of the North-West.[1]

Bubhor and Belaspur sections compared.—In the section on the Sutlej above Bubhór, fossils are found rather frequently in the middle Siwaliks, at a defined horizon, below some 4,000 to 5,000 feet of conglomerates. Proceeding up the river, we find, below and above Beláspur, between the Ghambar fault and the main boundary, a succession of strata that would in many respects answer to those of the Bubhór section: the hard red beds at the base are exactly similar; the middle grey beds are only more massive in the Bubhór section; but the conglomerates are quite different. The massive beds of Bubhór contain exclusively the rounded hard shingle only found in and near the great Himalayan torrents, whereas the conglomerates along the Náhan-Sirmúr junction in the Gamrola valley near Beláspur, even where cut by the Sutlej, are made up of local debris, principally of the hard sandstones of the Sirmúrs, but containing also pieces of the softer fossiliferous nummulitic beds of the Subáthu group. The lithological contrast is fully exhibited on the spot, for all about Beláspur, up to 200 feet over the river, there is a thick deposit of old Sutlej shingle, just like the Siwalik conglomerates of Bubhór, but probably of post-tertiary age, corresponding to

[1] In the description of this area published in 1864 (Mem. G. S. I., Vol. III) an arbitrary compromise had to be made on this score, as time did not admit of a further study of the ground. The Náhan zone was distinctively coloured up to the Sutlej; but in the country beyond, much the larger area being occupied by the higher beds, of presumably Siwalik age, the whole of that area was coloured as Siwalik, rather than attempt to put in from memory the outcrops of the lower horizons, presumably Náhan, along the several lines of upheaval. A compromise on similar grounds was made in the prolongation of the Sirmúr zone, on account of the total depression of the bottom nummulitic beds, and the appearance of higher beds, unlike any in the typical area. The paper referred to contains many more details than can be given here.

the similar boulder gravel capping the low hills of the Siwalik beds at Bubhór.

The easiest solution of the case is to accept these Gamrola conglomerates as upper Náhan beds; the fact, that Siwalik conglomerates hold a like relation of apparent conformity to lower Náhan beds in the Bubhór section, being disposed of through the peculiar conditions of deposition and disturbance shewn to have obtained in the Sub-Himalayan region. The case may be either complicated or simplified by the fact that farther north, along the same boundary at Dubrog, as already mentioned, conglomerates of the coarse shingle type are in force. As these descriptions are taken from a very cursory examination of the ground, it is likely that a proper survey will make all clear. Meantime such suggestions as are given may be of service to passing observers.

Doubtful beds in the Sirmur zone.—Our next example is taken from the Sirmúr zone. The structure of this rock-series in its typical ground, the outlier on the Lower Himalayan border, is somewhat different from what it is when forming an inner zone of the Sub-Himalayan area, from immediately north of the Sutlej. In the former position the lowest beds, the Subáthu nummulities, are always freely exposed in the low ground at the edge of the area, and detached patches occur outside the principal area; whereas the nummulitic beds north of the Sutlej are last found on rather high ground in the middle of the band, in the axis of an anticlinal flexure, and the highest beds of the series appear along the inner junction, dipping at a high angle towards the old rocks of the high mountains. It is so at least till we approach the flanks of the Dhauladhár range. As already explained, this inner Sirmúr line is now the main boundary of the whole section, and its general regularity of direction, combined with the features noticed, is suggestive of faulting. According to the arrangement described, the top beds of all are found at the apex of the curved inner boundary, a little north of the Biás. Between Dráng and Haurbágh soft light grey sandstones, undistinguishable from Siwalik rock, are succeeded by clays and conglomerates. The highest beds are exposed in the hill at Sih, and consist of massive bands of coarse breccia, rather than conglomerate, being composed of large and small angular debris of the cherty limestone and of the pink sandstone occurring in the ridge close by, towards which the conglomerates dip at 40°.

The peculiarly local character of these top deposits is very puzzling. It suggests some almost necessary modification of the simply faulted nature of the boundary, for the proximity to the old rocks at the time of formation must have been somewhat like what it is now. But the

strangest fact is, that although made up entirely of the Himalayan rocks recognisable in the ridge close by to the east, the most abundant rock of that ridge is not represented in the breccia, although in the actual talus of the ridge it asserts its necessary predominance. That rock is eruptive. The suggestion is very strong, that the intrusion of the igneous rock is of later date than these tertiary deposits; and this is the only observation by the Survey confirmatory of that made by General Strachey in Kumaun (see page 543), that the trap-rock of the Lower Himalayas is of tertiary age. No case of intrusion amongst tertiary beds has been noticed in the Biás area, where trap is in great force in the higher hills of Mandi. It is worth mentioning that no debris of tertiary rocks was found in these conglomerates of Sih.

Thus again here, within the inner zone of tertiary rocks, at the main boundary with the old rocks of the Lower Himalayas, and 50 miles from the outer zone of the Siwaliks, there are rocks which confront us as being possibly of Siwalik age; but the presumption is that they are older.

Want of fossils.—That so much disquisition should have been expended upon this difficulty, is already an admission that fossil evidence has hitherto failed us. But even this negative fact must at present have some weight in the argument. There is no recorded case of a fossil being found in these innermost beds of upper tertiary aspect, nor indeed in any upper beds inside the Ghambar fault, although that area includes a large portion of the Kángra district, and the whole of the ground known as the Kángra valley, where for many years Europeans have been accustomed to reside. The greater part of that area, moreover, between the lower tertiary zone and the Ghambar fault, is occupied by rocks which, but for the stratigraphical difficulties mentioned, would be taken at once as equivalents of the accepted Siwaliks of the Bubhór section. Whatever horizon those beds belong to, it may be confidently expected that fossils are to be found in them; but it is well to emphasize the significance that may belong to any organic remains obtained from the Kángra valley.

The base of the Dhauladhar range.—The features of the tertiary contact-zone, on the north of the Kángra district, along the base of the Dhauladhár, present peculiar features of interest. Nowhere else are these late deposits brought so near to the oldest Himalayan rocks. Above the sanitarium of Dharmsála, which stands on the Sirmúr zone, the space is not more than one mile between the tertiaries and the "central gneiss," which rises precipitously in the rugged crest of the Dhauladhár to above 16,000 feet in elevation. As might be expected, the general stratigraphical features are different in such a position from those of the

Lower Himalayan region. The general view suggested at first sight is, that the gneiss occupies the axis of a huge folded flexure, in which even the Siwaliks partook. This view would agree with the opinion sometimes expressed, that the whole Himalayan mountains have been upraised since a late tertiary date; and indeed the prodigious disturbance the tertiary rocks have undergone is sufficient testimony of the great changes that have been effected within that time. It would, however, be most difficult to maintain that the tertiary rocks had ever extended much beyond their present limits. This can at least be asserted for the beds immediately outside the Sirmúr zone: the enormous accumulation of tertiary river-shingle conglomerates along the base of the range west of Bhágsu to beyond the Rávi implies the proximity of an area of erosion to the north.

The case is different for the Sirmúr series; and increasingly so to the west. At Dharmsála these rocks affect a synclinal structure next to the main boundary, but the junction is well defined. At some spots to the west, as along the Chaki, the Sirmúr beds are scarcely, if at all, represented; and at the western extremity of the range, over the Rávi, they are so crushed together with the older rocks as to be inseparable from them, or else so altered as to be unrecognisable. The particular section referred to is at the head of a great fan on the left bank of the Rávi below Simliu, where the Sirmúr beds pass transitionally into a green pseudo-amygdaloidal trappoid rock, very similar to a rock of the Pir Panjál that is currently accepted as trappean. The section is so distinct as to have suggested that the Panjál rock would turn out to be altered Sirmúrs. This conjecture has not been confirmed; but it illustrates the degree to which the lower tertiary rocks are implicated in the structural features of the Dhauladhár. It is worth mentioning that on an outer outcrop in this position, a bed with obscure leaf marks was found, exactly like that of Kasauli, and so far suggesting the integrity of the Sirmúr group.

The Mandi rock-salt.[1]—As it is still a disputed point whether the rock-salt of Mandi belongs to the Sub-Himalayan or the Lower Himalayan rocks, it will be most appropriate to notice it in this section treating of the Kángra district. The rock is known in the country as "black-salt," in contradistinction to the pure mineral of the Salt Range. It has a dark, purplish hue, is quite opaque, and contains about 25 per cent. of earthy matter, the salt itself being nearly pure sodium chloride. It is only used by the poorer classes, after being subjected to a purifying

[1] Mem. G. S. I., III, Pt. 2, p. 60.

process by fire and water. Small nests of crystalline salt occur, but so rarely as to be reserved for the use of the Rajah and his household. The mines or quarries are at Dráng and Guma, 14 miles apart.

The salt occurs in a constant position, at a short distance within the well-defined boundary between the tertiary sandstones and the slaty calcareous rocks, apparently all belonging to the Lower Himalayan series, which are here, on the margin of the Biás basin, in a state of extreme disturbance, with abundant trappean intrusion. Its occurrence in a constant position along the general strike of the associated strata, and the distinct lamination in the rock itself, sufficiently prove its sedimentary origin. But besides the earthy matter, laminated or diffused, the salt commonly contains small angular pebbles, principally of pink quartzite and of limestone, very like the rocks of the adjoining ridge; and where the salt itself is wanting, this character is often found in a calcareous rock in the same position in the section, as in the Sukéti, a few hundred yards above its confluence with the Biás, and again in the Kángra district, in the river east of Bír (Beer).

The presence of these pebbles may have suggested to Mr. Theobald his opinion,[1] that the salt-rock of Mandi and the narrow band of rock between it and the main boundary are of nummulitic age. The fact already mentioned, that the Subáthu nummulitic beds are not found in a recognisable form throughout the greater part of the Sub-Himalayan zone in the Kángra area, gives at least negative support to this conjecture; and positive support may be found in the fact observed in this same area, as mentioned in the preceding section, how the nummulitic rocks here have been to some extent disguised beyond recognition, so as to be more akin in appearance to the old rocks than to their real associates of the tertiary zone.

North-western termination of the Kangra area.—The outer Siwalik range of the Kángra area does not cross the Biás. The second (Parwain) range, also of that region, ends at Patháukót, east of the Rávi. This extinction in echelon of the outer Sub-Himalayan ranges is structural, and not merely due to denudation. It will be shewn that the termination of the Dhauladhár east of the Rávi is probably of a similar nature, and the coincidence of these homologous features in the newest and oldest rocks in this terminal Himalayan region is noteworthy, although no very direct connexion can be suggested, except that the reduction of dimensions of the mountain-features took place in a like fashion in each zone, whether synchronously or not.

[1] MS. report.

THE JAMU AREA: **boundaries.**—Jamu (Jum; is the capital of the Sub-Himalayan territories, and the winter res?, of the Maharaja of Kashmir; and the name may appropriately be tfor this section of the Sub-Himalayan zone, the limits of the areag also very well marked by physical characters.[1] The Jhelum is tlstern boundary, where its course lies in the axis along which alstrata bend at an acute angle from their Himalayan strike into th the mountains of Hazára and of the Salt Range, on account on fact it has been chosen as the limit between the Himalayas r and the Punjab hill regions, described in the preceding chapter. west boundary of Jamu is the Rávi, which also coincides with a marked stratigraphical node.

Special feature.—As the peculiar expans the Náhan zone of the Sub Himalayas in the Kángra area corried with the extinction com e Lower Himalayan region, so the peculiar character of the Sand imalayan region of Jamu is the ern of the Sirmúr zone, take th s rise from the abrupt extinction Dhauladhár axis at the Rá cous his inward step of the lower t zone corresponds with that o the outer zone: the two ou r Siwalres of the Kángra area having died out, the outermost range of tnu area occurs on the prolongation of the Badsar-Nurpúr dislocatic

Sirmur zone at the Ravi.—The chan features from the Kángra to the Jamu area is otherwise so decide it is remarkable that the two master-dislocations of the Kángra area Jhambar-Basauli and the Badsar-Nurpúr faulted flexures—continue at a check or turn across the Rávi. The contrast they prese this way with the boundaries of the inner tertiary zone is very g: the Sirmúr band makes two abrupt, nearly rectangular, bends Rávi; and the river runs for about 7 miles in a south-south-west n along, not across, the local strike, where the whole series of fori bends round across the termination of the gneissic axis of the Dhr. The condition of the Sirmúr rocks at their inner contact suggs already described, complete participation in the intense contortie older rocks; while on the outside, the Sirmúrs are in sharp contrast mparatively fresh-looking conglomerates. These are enormously th not very coarse, as the upper Siwalik conglomerates always are e great rivers. Debris of the Sirmúr sandstone occurs in these glomerates; but

[1] The maps published with the following papers are on the , and, when joined together, give a fair view of the features noticed in the te Himalayan Country between the Ganges and the Rávi, Mem. G. S. I., III; Jamu and , Rec. G. S. I., IX; North-West Punjab, Rec. G. S. I., X.

here again it was observed that the pseudo-amygdaloidal trappoid rock is not represented, although it constitutes at present the most abundant detritus at the surface. These outer rocks, too, are greatly disturbed, being for the most part vertical along the south-south-west strike, so that we cannot say that they have not been subjected to the whole disturbing action; and the abrupt contact of beds of very different horizons would suggest faulting. Taking everything into consideration, however, it seems probable that this line of junction is not primarily a fracture, or at least that its form has been determined by local features of the surface, in the same position as those now so conspicuously developed. It is an illustration in this ground of the slow process of growth of the mountain structure, already illustrated from other sections.

Western expansion of Sirmur zone.—The suppressed and disguised condition of the Sirmúr zone is one of the peculiarities of the Sub-Himalayas of Kángra, where the Subáthu (nummulitic) group has not been detected throughout a distance of more than 100 miles south-east of the Rávi. The expansion of this zone and the free exposure of the bottom group, and even of the supporting rocks, are, on the contrary, the most marked features of the Sub-Himalayan area of Jamu. In this last respect the Jamu tract resembles the original Sirmúr area in the Lower Himalayas of the Simla region, except that in the latter instance the tertiary strata lie as outliers on the old rocks of the mountains, whereas in Jamu the old rocks appear as inliers in the Sirmúr zone. This comparison might only imply a relation of degree in the amount of denudation the two areas had undergone; but the case is far otherwise: there is a great difference in the stratigraphical relations of the two rock-series in the east and in the west, confirming in a very marked way the opinions arrived at, from the study of the upper tertiary groups, regarding the growth of the mountain-system. It is also to be particularly remarked that in Jamu as in Kángra, but not in the Sirmúr area, the nummulitic rocks never occur at the inner boundary of the zone.

At the Rávi the Sirmúr band is less than a quarter of a mile wide. It expands gradually to nearly 20 miles at the road from Jamu to Kashmir; at Rajauri it is reduced to 12 miles; and farther on, at the Púnch, it is nearly 30 miles wide. As in the case of the upper tertiaries of the Kángra area, this expansion and irregularity is due to the unsteadiness of the inner (main) boundary—a character which appears to shew that that boundary is more probably due to original[1] features of the ground, than to subsequent faulting; while the outer

[1] See note, p. 528.

boundary is very steady in direction, and is clearly connected with faulted flexures. This latter feature dies out in an anticlinal axis to the north-west of Kotli on the Púnch, before reaching the Jhelum; and to the south-east, except for its concealment at the Biás, it is more or less continuous with the Náhan-Sirmúr boundary of the Simla region, the "main boundary" of the tertiary zone in the middle Himalayan region. This resemblance or even correspondence with the main boundary of the Lower Himalayas east of the Sutlej is further increased by the appearance of the great limestone inliers along this line in Jamu; yet the discussion of the feature in the Simla region seemed to be against its being primarily a fault there.

Within 15 miles of the Rávi, above the village of Marún, over the Pain (Pine) river, a thin calcareous layer with nummulites was observed, high in a thick section of red shaly clays at the outer edge of the Sirmúr zone. The occurrence of even these upper Subáthu beds along this boundary is not, however, constant. On the contrary, something like a regular succession of high and low beds, occupying alternating intervals across the Sirmúr zone, as of waves along the strike, is very observable in the Jamu area. It is well exhibited in connexion with the great inliers.

Inliers.—These protruding masses of old rocks within the Sirmúr zone occur in two pairs: the Lápri and Sangar-Marg ridges on the Chináb, and the Ranjoti and Debigarh ridges near the Púnch. They are formed of hard limestone, conjectured to be of palæozoic age, with subordinate flaggy sandstones, and they stand out high above the surrounding tertiary strata,—a result due proximately to denudation. Lápri has an elevation of 9,914 feet, and seems to be protruded abruptly through the red beds of the Sirmúrs, no distinctively Subáthu beds having been observed near it. Sangar-Marg, 6,676 feet high, is the largest of these inliers, being more than 30 miles long, and 5 to 8 miles wide; the Chináb passes by a deep gorge exactly through its centre, just above Riássi.

Characters of the Subathu group.—The marked character of the bottom Subáthu beds makes it easy to distinguish the base of the tertiary series. The composition of this group in the Jamu area differs from that exhibited where the formation was originally described in the Simla region. In the latter ground the calcareous element is very subordinate and scattered, whereas throughout the Jamu hills all the limestone is concentrated in a steady and purely calcareous band near the base of the group. It is constantly underlaid by a band of carbonaceous shales not found in the Simla region, and often including a coaly layer. Thus it

would be very easy to distinguish lithologically an upper and a lower division of the Subáthu group in this western area. But the most constant rock of all is the pisolitic ferruginous clay already mentioned as the bottom rock in the Subáthu section, an exactly similar bed to which is found in the same position all through the Jamu hills; and the same occurs again in the Salt Range, where, at the east end at least, the nummulitic group is represented by these three bottom bands of the Subáthu group of the Jamu region. This fact is noticed here in order to record a suggestion regarding this peculiar bottom bed: in some respects it very much resembles a form of the high-level laterite of the peninsular area, the differences being easily attributable to contingencies that have affected the Himalayan rocks; its remarkable constancy over so large an area is also a strong point of similarity with the laterite, in which this uniformity, at great distances and when surrounded by very different rocks, is so puzzling a character; and lastly, this Subáthu bottom bed is on the geological horizon, already suggested [1] as probable in the case of the high-level laterite formation of the peninsula, and a similar rock has been already noticed on the same horizon in Guzerat,[2] Kachh,[3] and Sind.[4]

Relation of tertiary to palæozoic rocks.—In Sangar-Marg and in the western inliers the original relations of the tertiary series to the old rocks is fully exposed, and in all it presents itself as perfectly parallel superposition. It is difficult to conceive that a junction of palæozoic and tertiary strata can really be conformable, and a close examination will no doubt reveal some discordance; but it is certain that through all the contortions exhibited in these rocks the same contact beds are found together over large areas, and are, locally at least, quite conformable. This local conformity is exhibited at the very crest of the ridges; so these must be altogether due to disturbance of post-nummulitic date.

At many points all over the Sangar-Marg ridge, the Subáthu bottom bed rests upon a brecciated sandstone, associated with the great palæozoic limestone of the inliers. An ochrey iron ore has been extensively extracted from nests in these shattered top beds of the old formation, having probably been derived by infiltration from the coaly and ferruginous beds below the nummulitic limestone. In this great limestone itself the bedding is

[1] *Ante*, p. 364. The chapter on laterite had unfortunately been printed off before this remarkable confirmatory evidence of the theory there put forward as to the origin of high-level laterite had been recognised.

[2] *Ante*, p. 340.

[3] *Ante*, p. 345.

[4] *Ante*, p. 457.

often very obscure, but with such characteristic junction beds the relations of the two formations are very well seen: how the old limestone, as yet uncontorted, must have formed the floor of the nummulitic deposits, and was brought up and exposed on the axes of great complex anticlinal flexures, the covering beds having been more or less removed during the process of upheaval.

At the north-west angle of Sangar-Marg the axis of one of these flexures is very well seen, the old limestone disappearing under a saddle of the nummulitics, which continue exposed for many miles in the valleys to the west, a middle rib of the old limestone appearing again at two points of the outcrop. Copious hot sulphurous springs occur at Barmandal in the nummulitic coaly beds close to this axis, and again hotter springs at the point of the Ranjoti ridge, on the banks of the Púnch, where a corresponding anticlinal feature is well seen. Along the valley of the Choti Táwi, east of the Chináb inliers, and to the west, in the valley of the Bari Táwi, between the two groups of inliers, much higher beds of the Sirmúr series are found, on the very strike of the older rocks, thus shewing longitudinal undulation of the disturbance, as already mentioned.

Compared with sections of Simla region.—The contrast between the relations of the Subáthu group to the older rocks of the Jamu inliers and of the Simla region is a very noteworthy point in the history of the Himalayan region. The full effect of the evidence depends a good deal upon the identity of the old limestones of the two regions, and upon this, as will be explained, different conjectures have been offered; but even supposing the Jamu rock to be carboniferous, and the Król limestone to be triassic, the difference would still be important. In both areas the parallel superposition shews that the contortion of the old rocks occurred after the deposition of the eocene strata; in the Simla region, however, the nummulitics were deposited close to the limestone, but on beds a thousand feet below its horizon, *i. e.*, on an area where the limestone had been deeply denuded: whereas in Jamu the same nummulitics were laid down evenly over the limestone itself. Supposing the limestones the same, the facts would imply that the eastern area had been for long exposed to denudation as a land surface, while the western had been by some means protected from erosion. Analogous conclusions, as to an earlier elevation of the Lower Himalayan area, have been already strongly suggested from a comparison of the Náhan-Sirmúr and Siwalik-Náhan relations to east and west of the Sutlej.

Doubtful newer rocks of the Sirmur zone.—In the Sirmúr zone of the Jamu hills we have again to encounter a puzzle noticed in the Kángra area. Passing west from the Rávi along the inner (main) boundary, higher beds in the tertiary series are found, not accounted for by difference of

elevation, apparent conformable sequence being observed throughout. At several places in the upper Táwi valley, below the Bindi gap, coarse massive conglomerates are nearly vertical, close along the boundary. The peculiarity of these beds as compared with those noticed in a like position at Sih (page 556) is, that the partially rounded shingle of the Táwi conglomerates, containing some blocks 2 feet in diameter, is made up almost exclusively of bottom tertiary sandstone.

The question whence was derived this ancient tertiary debris, at the present inner edge of the tertiary area, is of much interest. The conglomerates occur just where the river, within 10 miles of its rise on the Kúnd-Kaplás mountain, 14,241 feet high, crosses the main boundary from the north-east. This mountain ridge has not been examined, but all the detritus in the river at present is of metamorphic rocks, and there is no known occurrence of tertiary sandstones to the north of the Sub-Himalayan boundary nearer than the basin of the upper Indus in Tibet. Their sub-angular condition and size give a strong presumption that the blocks of comparatively soft sandstone forming these conglomerates have not travelled far; and these fragments may possibly have been derived from some tertiary rocks exposed by a line of early disturbance in the area to the south. The probability seems, however, in favour of the blocks having come from the northwards, beyond the present main boundary; and what we know of the processes of disturbance in these mountain sections, would admit of a very limited range to this former extension of the tertiary deposits. The rocks at the edge of the supposed tertiary basin may have been slowly, but abruptly, turned up along a monoclinal flexure; as thus indurated and exposed to denudation, their debris may have been laid down in conformable sequence upon their undisturbed main area, until the fracture supervened, which resulted in the present steep contact with the ancient supporting rocks. Or it might be possible to derive these blocks from the exposed top of an anticlinal flexure in a former great spread of these lower tertiaries to the north, possibly continuous with the very similar deposits of the Indus valley in Ladák. Independently of geological considerations, the law of parsimony (to favour the least laborious process) inclines to the former supposition; and in any case it is highly probable that the area of denudation was close by when these conglomerates of coarse sub-angular debris were formed.

The question of the age of these conglomerates of the Sirmúr zone is rendered more difficult in this position from the fact of their containing Sirmúr debris. Independently of this, the great thickness of the series implies a great difference of age (in years) between the top and bottom

beds; and it is evident that undei the synchronous *pari passu* operations of disturbance and deposition, as urged for the whole Sub-Himalayan zone, the presence or absence of even great local unconformity is of comparatively little import, and thus sore ordinary stratigraphical criterions of relative age fail us here. There are other beds in this zone that would even more directly suggest a muc later age than any Sirmúr beds of the standard area; as on the band of 'epression of the Choti Táwi, there is a considerable thickness of soft pe clays north of Chinéni, more like upper Siwaliks than anything else. They are topmost beds, but in apparent sequence with all the other strata f the Sirmúr zone. It would be very rash at present to say that any of ·ese rocks are Siwalik; yet it is seemingly awkward to include, as Sirnir, beds made up of middle Sirmúr debris. Fossils only can decide these questions, and as yet none have been found in these beds.

Other general features of Sirmur zone.—Such very fresh looking rocks as those on the Chota Táwi have not been observed elsewhere in the Sirmúr zone of this area, but large portions of the ground have not even been traversed. On the Chináb secon only low red beds are exposed, higher beds prevailing again on the Rajauri section. The course of the Jhelum in the Sirmúr zone below Uri is with the strike of the rocks, along a broken anticlinal, having the usual upthrow to the north. A continuation of this feature is traceale southward towards Rajauri; and east of the dislocation, in the ridge (the Háji Pir, there is an outcrop of Subáthu limestone. The princip deformity of the directior of the main boundary is north of Rajaui where there is a broad angular projection of the rocks of the Pir Pan,l; it is in such positions that test sections of the true nature of the con'ct are most likely to be found.

No study has yet been made of tt remarkable feature at Musafarábád, close to the confluence of the Khenganga and the Jhelum, where the main boundary, with the strike of all the rocks and the course of the Jhelum, bend at an acute angle 35°) from the direction of the Himalayan ranges. The position seeis approximately coincident with the introduction or expansion of tl nummulitic limestone to the westward; and for some little distance on the Himalayan side of the bend this rock occurs at the boundar. Such coincidences of original with induced stratigraphical characters re often very suggestive of correct interpretations. To the south-wesof this point, in the Hazára hills, the whole character of the bottom te·iary zone is changed: instead of a continuous main boundary, separaing all the tertiary deposits from the rocks of the higher range, as in the Himalayan region, we find the nummulitic beds folded up promiuously with the underlying

formations, resulting in a very patch-work appearance of the outcrops, as shewn in a map. Thus the nearest physical equivalent of the main boundary of the Sub-Himalayas should be near Abbottabad rather than near Murree.[1] This contrast might, of course, be due simply to greater elevation and denudation of the western area; but it is probably further connected with other original points of difference between the two areas, besides the one already mentioned: in the trans-Jhelum ground other formations (jurassic and triassic) are introduced between the Subáthu group and any representative of the palæozoic limestone of the Jamu inliers.

The Siwalik-Sirmur boundary.—Pending the palæontological determination of the equivalent horizons in these several zones of similar rocks, little more can be done than to describe these mere rock-features. The outer boundary of the Sirmúr zone of the Jamu area, on the prolongation of the main boundary of the Lower Himalayan region, has already been noticed as mainly a fault-line. This is strongly suggested by the straightness of the feature; and everywhere along it, beds of different horizons are in contact, till at last, within a few miles of the Jhelum, it dies out in an expanded anticlinal flexure, where again, as on the Biás, one can pass from the Siwalik to the Sirmúr zone without a break. Thus this feature, whether dislocation or not, of principal magnitude and persistence throughout the whole Himalayan border, comes to an end within the Himalayan limits, not like the more simple features of disturbance, recognised as primarily faults or flexures, which are continuous with like features beyond the Jhelum. There is one remarkable irregularity of this boundary at the Chináb; and the normal direction of the Siwalik zones undergoes a corresponding deflection in this position. At Riássi, where the river passes through the Sangar-Marg inlier, there is a wide bay in the south face of the limestone ridge, making a very marked indent in the course of the outer Sirmúr boundary.

The Basauli-Naushera fault.—On the Rávi, where a much more abrupt twist affects the inner tertiary (Sirmúr) zone, it was noted that the great dislocations in the Siwalik zone swept past it with little or no deviation. It is not so at the Chináb: the Ghambar-Basauli fault curves northwards into apparent, or actual, continuity with the eastern face of the Riássi bay, thus cutting off the inner Siwalik zone of Udampur and Kángra. This effect is, however, not permanent, for an equivalent dislocation emerges in continuity with the western side of the bay,

[1] In the North-West Punjab Map, referred to in the note, p. 560, the boundary west of the Jhelum, continuous with the main boundary to the east, is probably a junction of upper and lower Subáthu beds.

and forms the Naushera faulted anticlinal, with the Kotli synclinal dún between it and the Sirmúr zone, representing the Udampur dún to the east. The Naushera dislocation is as important as its eastern representative; it curves round across the Jhelum, north of Mount Narh, passing south-westwards towards Ráwalpindi.

Riassi conglomerates.—The actual continuity of this Basauli-Naushera dislocation, round the edge of the Riássi bay, may possibly be maintained. There are no observations to settle the point, or to shew the relation of this dislocation with the outer Sirmúr boundary, where the two are confluent at the base of Sangar-Marg. Thus it would seem that the conglomerates on the Chináb, in the Riássi bay, belong as much to the middle as to the inner Siwalik zone; and there is strong presumption that they correspond in age to the conglomerates of the inner zone on the Rávi, north of Basauli. In both cases the conglomerates occur in force only near the great rivers.

The outer Siwalik zone.—The Riássi bay is most marked in the outer Siwalik zone. The Badsar-Núrpúr anticlinal, which is a conspicuous feature throughout the lower hills of Jamu to beyond the Jhelum, where it bends south-westwards to Kahúta, makes a deep swerve northwards at the Chináb, so that the outermost Siwalik range north of Jamu runs due north and south for some distance. This corroborates the suggestion that the Basauli-Naushera dislocation does actually run up to the inner boundary under Sangar-Marg. The elucidation of this very exceptional feature, in connexion with the great inlier, would form an interesting study.

Outside the Badsar-Núrpúr flexure there is no great continuous dislocation passing across the Jhelum from one direction of strike into the other, as in the deeper sections to the north: a number of local independent flexures pass off more or less obliquely from the Himalayan strike, to terminate in a reciprocating manner with the flexures of the Salt Range system.[1] This arrangement exhibits, in even a more convincing manner, a synchronous action in both directions of disturbance. In this struggle for room the Salt Range system seems to have had the best of it: flexures belonging to it are more persistent in overlapping the Himalayan series. The last example of this is the Pabbi or Kharián anticlinal ridge, consisting of Siwalik rocks, striking due north-east close up towards, and at right angles to, the Sub-Himalayan ranges at Bhimbar; its prolongation for 18 miles would thus strike the great Siwalik dislocations on the Bari Táwi, more than 50 miles from their diversion on the Jhelum. This outlying Kharián flexure is altogether east of the

[1] See maps quoted in note, p. 560.

Jhelum, and forms the only exception to this river forming an exact boundary of the Sub-Himalayan system.

SUMMARY.—As other considerations made it necessary or desirable to break up the description of the Sub-Himalayan zone into sections of areas more or less natural or arbitrary, we must now endeavour to indicate connectedly the chief points of evidence upon which inferences have been based regarding the history of the mountains.

1. Special Himalayan disturbance altogether post-eocene.—Where the original relations of the lowest tertiary deposits, the Subáthu nummulitic group, to the very ancient (palæozoic) rocks of the mountains are exposed in the Simla region (p. 532) and in Jamu (p. 563), we learn that these old rocks had then undergone no contortion, where now contortion is extreme. We might thus infer that the Himalayas, *as a region of special disturbance*, had then made no beginning, and for this southern zone of the mountains this inference is conclusive; but there are other facts to qualify it as regards an earlier stage of Himalayan elevation.

2. Eocene Himalayan land.—The remnant of lowest tertiary rocks preserved on the margin of the Lower Himalayas in the Simla region, reveals other original relations not elsewhere discoverable—(*a*) the old rocks had here been deeply denuded (p. 533), as by subaërial denudation; (*b*) the Subáthu beds here are very variable in thickness (p. 533), suggesting proximity to a limit of deposition to the north-east; (*c*) the marked deficiency in these Sub-Himalayan nummulitics of open sea deposits or organisms (p. 531) suggests at least estuarine conditions; (*d*) the regular succession here of deposits of true Sub-Himalayan type (pp. 525, 530) carries on this suggestion, implying that before any special contorting action had set in, the general conditions of Sub-Himalayan deposition had been established by a general (continental) elevation of the Himalayan area. The presence of terrestrial plants in the Kasauli beds also proves the proximity of land.

3. Doubtful extension over the Lower Himalayan area.—Even in the Simla region, the border of that eocene Himalayan land is only approximately and conjecturally indicated. The inner boundary of this Sirmúr outlier is quite different from any line of junction in the Sub-Himalayan zone (p. 534): these latter are universally, to some extent or other, special features of Himalayan disturbance, forming single continuous lines of boundary; whereas the former is the outcrop of an irregular surface of deposition that had subsequently undergone simple corrugation and denudation. As regards the country to the north-west, the absence in the old rocks of Jamu (p. 564) of the denudation which is so marked in the Simla region, suggests that the long pre-

tertiary elevation of the Lower Himalayan region had not extended to the north-west. The features of the boundary in this direction also leave it an open question how far the tertiaries may have extended: we find these either amalgamated with the older rocks in their most extreme condition of disturbance (p. 558), or in abrupt faulted contact (p. 565), both states implying some former extension; so there remains only the fact of composition to suggest that there, too, there was a neighbouring eocene land.

4. Actual Himalayan border defined in middle tertiary times.—To the east of the Simla region the case is the reverse of that described to the west: no trace of lowest tertiary rocks has been found in the Sub-Himalayan zone in this direction (p. 534); the Sirmúr rocks seem to have been uplifted, and more or less completely removed by denudation, in early tertiary times (pp. 534, 540), when the present Himalayan border was defined. The only connection suggested for the Subáthu group in the east is the strikingly similar nummulitic beds in the Gáro hills, at the west end of the Assam range (p. 535).

5. Its partial extension to the north-west.—This first great act of Himalayan disturbance in tertiary times, as just recorded, again resulted in the elevation of the Lower Himalayan as compared with the north-western area, producing the Náhan-Sirmúr unconformity, and the main boundary of the whole middle Himalayas. In the north-west the Náhan-Sirmúr boundary is the most important structural feature within the Sub-Himalayan zone; and there, too, it is doubtfully a feature of simple dislocation (pp. 560-1). The elevation in the east seems to have taken place earlier: seemingly newer rocks occur in the Sirmúr zone north of the Sutlej than in the Simla region (p. 556).

6. Himalayan river-gorges in Siwalik times same as now.—The great accumulation of conglomerates, and their marked variation in quantity and quality in relation to the great Himalayan torrents, are most marked in the outer Siwalik zone (pp. 541, 551); and the fact admits of no other explanation than that the gorges of these torrents in the adjoining mountains were then in the same positions as now, and have not been sensibly changed by the prodigious disturbance to which these latest Siwalik deposits have been subjected (pp. 541, 551). In the north-west similar accumulation and distribution of conglomerates are found in the inner Siwalik zones (p. 568). Whether or not these prove to be of the same age as those on the outer zone on the same section, the fact is again suggestive of the earlier elevation and separation of the zones in the middle Himalayas.

7. Extreme slowness of disturbing action.—The extreme slowness with which such great operations of disturbance were accomplished

is sufficiently attested by the fact related in the preceding paragraph regarding the great rivers; the inference being especially illustrated by the case of the Sutlej at Bubhór (p. 551). This case illustrates, too, a constant puzzle in these Sub-Himalayan sections—the close conformable sequence between strata that were virtually strongly discordant. The same process of simultaneous deposition and disturbance gives us some explanation of the prodigious thickness of these deposits—a thickness that would appear excessive if the measurements had to be understood as vertical dimensions.

8. Elevation preceded compression.—One important inference upon the theory of mountain-formation is apparent from these observations on the Sub-Himalayan zone. Special Himalayan disturbance is now nowhere more strongly marked than in this fringing zone; and it has all occurred since a middle tertiary date, for the oldest rocks were then unplicated in this position. Yet a considerable Himalayan elevation had occurred in pre-tertiary and early tertiary times; and this elevation must, therefore, have been of the nature of a simple protuberance *(bossellement)*, or warp, as suggested in De Beaumont's theory of mountain-formation; while some more modern theories seem to require that compression with contortion should be a first stage in the process of special elevation.

CHAPTER XXIV.

EXTRA-PENINSULAR AREA.

SIWALIK FAUNA.

The later tertiary vertebrate fauna — Siwalik mollusca — Homotaxis of mammalia — Reptilian evidence — Siwalik fauna probably pliocene — Stratigraphical evidence of age of Siwaliks — Survival of miocene forms in Siwalik beds — Pliocene fauna of Pikermi in Attica — Migration — Effects of change of climate — Comparative poverty of recent mammalian faunas — Relations of Siwalik to Perim Island fauna — Comparison with Irawadi fauna — Comparison of Siwalik and recent faunas.

The later tertiary vertebrate fauna.—In several of the preceding chapters reference has been made to the mammalian fauna found in the upper tertiary beds of Northern and Central India, and in five instances,—the post-pliocene faunas of the Gangetic plain [1] and of the Narbada valley,[2] the older pliocene mammalia of Perim Island,[3] and the miocene faunas of Sind[4] and of Kushalghar[5] in the Punjab,—lists of the species identified have been given. By far the most important collection of mammalian remains found in any Indian formation is, however, that of the Siwalik beds; and as many of the species found elsewhere recur in the Siwalik area of the North-West Provinces and the Punjab, it will be useful in the present chapter to give a general account of the later tertiary vertebrata of India and Burma.[6] The following is a complete list of all species[7] hitherto identified in the miocene, pliocene,

[1] *Ante*, p. 402.
[2] P. 385.
[3] P. 343.
[4] P. 471.
[5] P. 514.

[6] Crania and teeth of several species, and in two instances, *Astragali*, are figured in Plates XVII, XVIII, XIX, and XX. References are appended in the list of species.

[7] The majority of the tertiary vertebrata of India, discovered by Falconer, Cautley, Baker and Durand, were described by Falconer, most of whose writings, published and unpublished, are collected in his posthumous "Palæontological Memoirs." The greater portion of the following notes are taken from Mr. Lydekker's papers on the Siwalik fauna; Rec. G. S. I., IX, pp. 42, 86, 144, 154; X, pp. 30, 76, 225; XI, p. 64; and Pal. Ind., Ser. X, Pts. 2 and 3; and from some MS. papers by Mr. Theobald, who has collected a large number of the fossils described by Mr. Lydekker.

and post-pliocene deposits of British India and its dependencies, the distinctly miocene forms of Sind and the Punjab being distinguished by the letter M, and the post-tertiary mammals by Pl being affixed. To all forms that have been found in the Siwalik area, irrespective of horizon, the letter S is added; the species from Perim Island are distinguished by a P, and those from the Irawadi valley by I.

MAMMALIA.

PRIMATES.

S. *Macacus sivalensis.*
S. *M.*, sp.
S. *Semnopithecus*, sp.
S. ? *Semnopithecus subhimalayanus*, Pl. XIX, fig. 11.
Pl. *S.*, sp.

CARNIVORA.

FELIDÆ—
S. *Felis cristata.*
S. *F. palæotigris.*
Pl. *F.*, sp.
S. *Machærodus sivalensis.*
S. *Pseudælurus sivalensis.*

VIVERRIDÆ—
S. *Ictitherium sivalense.*

HYÆNIDÆ—
S. *Hyæna sivalensis*, Pl. XIX, figs. 8, 10.

CANIDÆ—
S. *Canis* (*Vulpes*), sp.

URSIDÆ—
S. M. *Amphicyon palæindicus*, Pl. XIX, fig. 4.
S. *Ursus*, sp.
I. *U.*, sp.
Pl. *U. namadicus*, Pl. XX fig. 6.
S. *Hyænarctus sivalensis*, Pl. XIX fig. 9.
S. *H. palæindicus.*

MUSTELIDÆ—
S. *Mellivora sivalensis.*
S. *Meles*, sp.
S. *Lutra palæindica.*
S. *Enhydriodon sivalensis*, Pl. XIX, fig. 5.

PROBOSCIDEA.

ELEPHANTIDÆ—
S. *Elephas* (*Euelephas*) *hysudricus*, Pl. XVII, fig. 5.
Pl. *E.* (*Euelephas*) *namadicus*, Pl. XX, figs. 5, 8.
S. *E.* (*Loxodon*) *planifrons.*
Pl. S. *E.* (*Stegodon*) *insignis*, Pl. XVII, figs. 1, 7.
Pl. S. *E.* (*Stegodon*) *ganesa*, Pl. XVII, fig. 2.
S. *E.* (*Stegodon*) *sinensis.*
S. *E.* (*Stegodon*) *bombifrons.*
S. I. *E.* (*Stegodon*) *cliftii.*
S. I. *M.* (*Pentalophodon*) *sivalensis*, Pl. XVII, fig. 6.
S. I. P. M. *Mastodon* (*Tetralophodon*) *latidens*, Pl. XVII, fig. 4.
S. P. M. *M.* (*Tetralophodon*) *perimensis*, Pl. XVII, fig. 3.
Pl.? *M.* (*Trilophodon*) *pandionis.*
S. M. *M.* (*Trilophodon*) *falconeri.*

DINOTHERIDÆ—
P. *Dinotherium indicum.*
M. *D. pentepotamiæ.*

UNGULATA.

A. PERISSODACTYLA.

RHINOCEROTIDÆ—

S. ***Rhinoceros platyrhinus.***

S. M. ***R. sivalensis***, Pl. XIX, figs. 1, 3.

S. M. ***R. palæindicus.***

S. ***R. planidens.***

I. ***R. iravadicus***, Pl. XIX, fig. 2.

Pl. ***R. namadicus***, Pl. XX, fig. 9.

Pl. ***R. deccanensis.***

S. *R.* 2 sp.

I. *R.* sp.

M. *R.* 2 sp.

S. P. I. ***Acerotherium perimense.***

TAPIRIDÆ—

I. *Tapirus*, sp.

M. ***Listriodon pentepotamiæ***, Pl. XIX, fig. 7.

S. ***L. theobaldi.***

EQUIDÆ—

S. ***Equus sivalensis.***

S. ***E. palæonus.***

I. *E.* sp.

Pl. ***E. namadicus***, Pl. XX, fig. 4.

S. ***Hipparion antelopinum***, Pl. XIX, fig. 6.

S. M. ***H. theobaldi.***

B. ARTIODACTYLA.

HIPPOPOTAMIDÆ—

Pl. ***Hippopotamus (Tetraprotodon) palæindicus***, Pl. XX, fig. 7.

S. ***H. (Hexaprotodon) sivalensis***, Pl. XVIII, figs. 1, 6, 8.

I. ***H. (Hexaprotodon) iravadicus.***

Pl. ***H. (Hexaprotodon) namadicus***, Pl. XX, fig. 2.

S. ***Hippopotamodon sivalensis.***

TETRACONODONTIDÆ—

S. ***Tetraconodon magnus.***

SUIDÆ—

S. ***Sus giganteus***, Pl. XVII, fig. 9.

S. ***S. punjabiensis.***

S. P. M. ***S. hysudricus.***

Pl. *S.* sp.

M. ***Sanitherium schlagintweiti.***

S. ***Hippohyus sivalensis***, Pl. XVII, fig. 8.

S. *H.* sp.

M. ***Hyopotamus palæindicus.***

ANOPLOTHERIDÆ—

S. ***Chalicotherium sivalense***, Pl. XVIII, fig. 4.

ANTHRACOTHERIDÆ—

M. ***Hyotherium sindiense.***

S. I. ***Merycopotamus dissimilis***, Pl. XVII, fig. 10.

M. ***Anthracotherium silistrense.***

Chæromeryx silistrensis.

M. ***Hemimeryx***, sp.

M. ***Sivameryx***, 2 sp.

CERVIDÆ—

S. ***Cervus latidens.***

S. ***C. triplidens.***

S. ***C. simplicidens.***

Pl. ***C. namadicus.***

I. *C.* sp.

S. M. ***Dorcatherium majus***, Pl. XVIII, fig. 3.

S. M. ***D. minus.***

CAMELOPARDALIDÆ—

S. ***Camelopardalis sivalensis.***

S. *C.* sp.

P. *C.* sp.

S. ***Sivatherium giganteum***, Pl. XVIII, fig. 7.

P. ***Brahmatherium perimense***, Pl. XVIII, fig. 5.

S. ***Hydaspitherium megacephalum.***

S. ***H. grande.***

S. ***H. leptognathus.***

I. ***Vishnutherium iravadicum.***

B. ARTIODACTYLA—continued.

BOVIDÆ—

S. ***Bos acutifrons.***
S. ***B. planifrons.***
S. ***B. platyrhinus.***
I. ***B.***, sp.
Pl. ***B. namadicus***, Pl. XX, fig. 3.
S. ***B.*** (***Bison***) ***sivalensis.***
Pl. S. ***B.*** (***Bubalus***) ***palæindicus***, Pl. XX, fig. 1.
S. ***B.*** (***Bubalus***) ***platycerus.***
S. ***Peribos occipitalis.***
S. ***Amphibos acuticornis***, Pl. XVIII, fig. 2.
S. ***Hemibos triquetricerus***, Pl. XVIII, fig. 1.
S. ***Antilope sivalensis.***
S. ***A. patulicornis.***
S. ***A. porrecticornis.***
S. ***A. palæindica.***
P. ***A.*** sp.
Pl. ***A.*** sp.
S. ***Capra sivalensis.***
S. ***C.*** sp.
P. ***C. perimensis.***
S. ***Ovis***, sp.

CAMELIDÆ—

S. ***Camelus sivalensis.***

RODENTIA.

MURIDÆ—

S. ***Mus***, sp.
Pl. ***M.*** sp.

SPALACIDÆ—

S. ***Rhizomys sindiensis.***

HYSTRICIDÆ—

S. ***Hystrix sivalensis.***

EDENTATA.

M ***Manis sindiensis.***

AVES.

S. ***Argala falconeri.***
S. Other bones belonging to the order *Grallæ*.

REPTILIA.

CROCODILIA.

S. ***Crocodilus crassidens.***
S. ***C. leptodus.***
S. ***C. palustris.***
P. ***C. perimensis.***
M. ***Crocodilus***, sp.
Pl. ***C.*** sp.
I. ***C.*** sp.
S. I. ***Gharialis gangeticus.***

LACERTILIA.

S. ***Varanus sivalensis.***

OPHIDIA.

S. M. *Vertebræ* indet.

CHELONIA.

S. I. ***Colossochelys atlas.***
S. I. ***Testudo***, sp.
S. ***Bellia sivalensis.***
Pl. S. ***Emys tectum.***
S. ***E.*** (***Batagur***), sp.
Pl. ***Emys*** (***Batagur***), cf. ***dhongoka.***
S. I. ***Emyda***, sp.
S. I. ***Trionyx***, sp.
Pl. ***T.*** sp. cf. ***gangeticus.***

Siwalik mollusca.—The few mollusca which have been found belong solely to fresh-water or terrestrial forms, and the only comparison hitherto made[1] was carried out under circumstances so unfavourable, with so poor a collection of recent species from India, and at a time when the latter were so imperfectly known, that but little weight can be attached to the conclusions formed. No good materials for comparison have been procured of late years, and the few specimens obtained are in poor preservation, but all the forms collected since the recent fresh-water shells have been better known have proved to be either identical with living species, or closely allied to them. Amongst those hitherto identified, the only land-shell is *Bulimus insularis*,[2] a species which ranges at the present day from Africa to Burma, whilst amongst fresh-water mollusks, the two common Indian river-snails, *Paludina bengalensis* and *P. dissimilis*, have been recognised, and forms of *Melania*, *Ampullaria*, and *Unio* also occur.

So far as the evidence extends, therefore, the few mollusca of the Siwaliks tend to shew that the beds must be of late tertiary date; for it is difficult to conceive that no important change in the species of fresh-water mollusca would have taken place had the strata been of miocene age. But the evidence afforded by the mollusca is imperfect, and both closer comparison and a larger series of fossil specimens are desirable before any very positive assertions can be made as to the antiquity of the formations on the data afforded by the *Invertebrata*. In investigating the question of age, we are consequently forced to depend, *first*, upon the *Vertebrata*, and especially the *Mammalia*; and *secondly*, upon such geological evidence of connection with other formations of known age as the rocks afford.

Homotaxis of mammalia.—The first question, then, is the homotaxial relation of the Siwalik mammalian fauna. The preceding lists, it should be repeated, embrace the whole of the collections of *Vertebrata* from the later tertiary beds of India; in dealing with the Siwaliks alone, we have therefore to omit all forms found solely—(1) in the lower Manchhar beds of Sind, and their probable representatives in the

[1] Prof. E. Forbes, in Falconer's Palæontological Memoirs, I, p. 389.

[2] Theobald, MS. As in this and the following paragraph Mr. Theobald's view of the affinities of the Siwalik mollusca has been accepted in preference to the high authority of Prof. E. Forbes, it is only just to say that Mr. Theobald has a far more extensive knowledge of living Indian fresh-water shells than it was possible for any naturalist in Europe to acquire at the period when Prof. E. Forbes' note was written. Indeed it is evident from Prof. Forbes' remarks that the collections of recent Indian shells examined by him were too imperfect to enable him to form a competent opinion. Mr. Benson, a far better authority on this particular subject than Prof. E. Forbes, considered the most, if not the whole, of the Siwalik mollusca identical with existing species: Falconer, Pal. Mem., I, pp. 26, 181.

Western Punjab;—(2) in the localities of Perim Island, the Irawadi valley, and certain beds of Sylhet;—and (3) in the post-tertiary clays and gravels of the Jumna, Narbada, Godávari, and other Indian rivers, so far as all such forms are unrepresented in the Siwalik area. This leaves a fauna composed of the following 45 genera, each represented by the number of species noted, the total number of specific forms being 84: extinct genera are marked with an asterisk:—

PRIMATES—

Macacus, 2; Semnopithecus, 2.

CARNIVORA—

Felis, 2; Machærodus (Drepanodon), 1; Pseudælurus,* 1; Ictitherium,* 1; Hyæna, 1; Canis (Vulpes), 1; Amphicyon,* 1; Ursus, 1; Hyænarctus,* 2; Mellivora, 1; Meles, 1; Lutra, 1; Enhydriodon,* 1.*

PROBOSCIDEA—

Elephas, 7; (Euelephas, 1; Loxodon, 1; Stegodon, 5;) Mastodon,* 4. (Pentalophodon,* 1; Tetralophodon,* 2; Trilophodon,* 1).*

UNGULATA PERISSODACTYLA—

Rhinoceros, 6; Acerotherium, 1; Listriodon,* 1; Equus, 2; Hipparion,* 2.*

UNGULATA ARTIODACTYLA—

Hippopotamus (Hexaprotodon), 1; Hippopotamodon,* 1; Tetraconodon,* 1; Sus, 3; Hippohyus,* 2; Chalicotherium,* 1; Merycopotamus,*1; Cervus, 3; Dorcatherium,* 2; Camelopardalis, 2; Sivatherium,* 1; Hydaspitherium,* 3; Bos, 6; (Bos* restricted, *3; Bison, 1; Bubalus, 2;) Peribos,* 1; Amphibos,* 1; Hemibos,* 1; Antilope, 4; Capra, 2; Ovis, 1; Camelus, 1.*

RODENTIA—

Mus, 1; Rhizomys, 1; Hystrix, 1.

Of a large proportion of the species only very imperfect information exists as to the exact horizon in the Siwalik series at which the bones have been found, but the great majority are from the upper and middle Siwaliks, none in the typical area being known to occur in the lower or Náhan sub-division. It is, however, by no means certain that some of the specimens from the North-Western Punjab are not derived from beds of the same age as the Náhan group. The mammals of Kushalghar have already been excluded from the list, because they, like the lower Manchhar species of Sind, evidently belong to an older formation than the fossiliferous portion of the Siwalik beds; and Núrpúr in the Punjab, the only other locality, besides Kushalghar and the Laki hills of Sind,

whence *Amphicyon* has been obtained, may also be upon older strata. It is highly probable that some other forms with middle tertiary affinities would be found to be confined to lower Siwalik beds, if the precise horizon of all the bones collected were known.[1]

On the other hand, one post-tertiary form, *Bos* (*Bubalus*) *palæindicus*, has been found in the highest Siwalik strata, associated with *Camelus sivalensis*, *Colossochelys*, &c.; and two species of elephant belonging to the sub-genus *Stegodon*, viz., *E. insignis* and *E. ganesa*, range throughout the upper Siwaliks, and recur in the post-tertiary deposits. The species of proboscidians generally appear to have had a more extensive range, both in space and time, than most of the forms belonging to other mammalian orders; but *Bos palæindicus* is an animal of exceptionally recent aspect, even in the post-tertiary mammalian fauna, since it is only distinguishable from the living *Bos bubalus* (*Bubalus buffelus* v. *B. arni*, auct.) by comparatively trifling and unimportant osteological details; it must evidently have been a very near ally, and, in all probability, the not very distant progenitor of the buffaloes which now inhabit the Ganges valley, Assam, and parts of the Central Provinces of India.

The Siwalik forms, however, which might be excluded on account of belonging to an older or a newer fauna, and of being supposed, on more or less strong evidence, to be confined to either the lowest or the uppermost portions of the series, are too few in number to affect the general facies, and there are unquestionably several miocene types and some post-tertiary species found in the highly fossiliferous upper Siwalik beds. It is best therefore, for the present, to include all the forms enumerated.

Proceeding, then, to classify the genera above given, it will be found that 24, comprising 53 species, still exist (the living species being however all, so far as is known, different), whilst 21, with 30 species, are extinct. If, instead of reckoning the larger genera, *Elephas*, *Mastodon*, *Hippopotamus*, and *Bos*, their sub-genera are counted, the result will be slightly to diminish the proportion of recent genera, the recent generic types becoming 26, with 47 species, the extinct 25, with 36 species. The former plan of classification is however, on the whole, preferable, because such distinctions as those between *Euelephas*, *Loxodon*, and *Stegodon*, for instance, are scarcely of generic value, the majority of the genera named, e. g., *Felis*, *Rhinoceros*, *Cervus*, *Antilope*, have not been sub-divided

[1] A very large proportion of the Siwalik remains have been obtained by native collectors employed in the search, and of course the precise locality of the bones is in most cases doubtful.

like *Elephas* and *Bos ;* and the affinities of the fauna are best understood by grouping the forms in somewhat larger sub-divisions than the sub-genera of older and the genera of many modern writers.

Taking the extinct genera first, the following ten are peculiar to the Indian tertiaries, so far as is hitherto known :—

CARNIVORA—

Enhydriodon.

UNGULATA ARTIODACTYLA—

Hippopotamodon, Tetraconodon, Hippohyus, Merycopotamus, Sivatherium, Hydaspitherium, Peribos, Amphibos, Hemibos.

Of the remaining eleven genera, four, viz., *Pseudælurus, Amphicyon, Listriodon,* and *Dorcatherium,* are only known in Europe from miocene beds, *Pseudælurus* being also found in pliocene rocks in America; whilst *Machærodus, Hyænarctus, Ictitherium, Mastodon, Acerotherium, Chalicotherium,*[1] and *Hipparion* are both miocene and pliocene; the first and fourth ranging into post-pliocene beds also; the former in Europe, the latter in America.

Of the other extinct forms, two, *Hippohyus* and *Merycopotamus,* belong to the less specialised types characteristic in general of the older and middle tertiaries. Several others, such as *Tetraconodon,* with its enormously developed premolar teeth, and the huge four-horned *Sivatherium,* differ widely from anything now existing; but being highly specialised forms, there is nothing in their organisation to indicate that they are of earlier age than newer tertiary.

Amongst the recent genera represented in the Siwaliks, eight, viz., *Felis, Hyæna, Canis, Lutra, Rhinoceros, Sus, Cervus,* and *Antilope,* are known to range as far back as upper miocene, and in one or two cases even further; ten, viz., *Macacus, Semnopithecus, Ursus, Elephas, Equus, Hippopotamus, Camelopardalis, Bos, Hystrix,* and *Mus,* are known from the European pliocene beds, but not earlier; and several are poorly represented, or only known in newer pliocene strata; whilst the following, *Mellivora, Meles, Capra, Ovis, Camelus,* and *Rhizomys,* have hitherto only been found recent, or in post-pliocene deposits.

This examination of the relations between the Siwalik genera and the distribution of similar forms in European tertiaries leads, as might be anticipated, to a somewhat uncertain result. The proportion of living to extinct genera is greater than is found in most miocene deposits, but not more than appears to exist in the characteristically middle tertiary

[1] *Acerotherium* and *Chalicotherium* are found in pliocene beds at Pikermi: see page 583. *Ictitherium* occurs in the pliocene of Pikermi, and in miocene beds in Bessarabia and in France.

ossiferous beds of Sansan in France.[1] The presence of four extinct genera not known to range above the miocene period elsewhere is contrasted with the occurrence of sixteen genera not found elsewhere at a lower horizon than pliocene or post-tertiary. There is perhaps rather more probability that early forms like *Chalicotherium* and *Amphicyon* should have survived longer in India than they did in Europe, just as rhinoceroses, tapirs, and elephants still exist in the tropics, associated with a fauna amongst which they appear antiquated and out of place, than that such eminently specialised types as *Macacus*, *Bos*, *Capra*, or *Equus* should have lived in miocene times; but the argument is of small value, for the miocene *Cervus* and *Antilope* were in all probability as highly specialised, or nearly so, as the Siwalik genera. The fact, however, that the recent genera contain more species than the extinct forms is of some importance, since it is probable that types which were dying out would be represented by fewer species than those which were supplanting them, and which might fairly be credited with the vitally important power of producing distinct specific stocks by variation. A stronger argument for the newer age of the Siwalik beds is to be found in the close approximation between some of the mammals and the living species of the same genera, the most remarkable of all being the connection, already noticed, between the fossil buffalo of the uppermost Siwalik strata, that of the post-pliocene Jumna and Narbada beds, and the common Indian species now existing.

Reptilian evidence.—The evidence afforded by the few species of reptiles sufficiently known to be of importance is decidedly in favour of attributing to the Siwalik beds a later age than miocene. Only six species are sufficiently well known to be fairly comparable, and three of these, *Crocodilus palustris*, *Gharialis gangeticus*, and *Emys tectum*, are common living forms now inhabiting the same area; whilst *Emys* (*Bellia*) *sivalensis*[2] is very closely allied to a living Burmese species, *E. crassicollis*. *Crocodilus crassidens* and *Colossochelys atlas* differ considerably from all living forms, and *Crocodilus leptodus* is very imperfectly known.

Siwalik fauna probably pliocene.—Putting together the whole data derived from *Mammalia*, *Reptilia*, and *Mollusca*, it is impossible to deny that the balance of evidence is in favour of a pliocene age. This is opposed to the general consensus of European geologists hitherto,[3] and it

[1] Gervais, Zool. Pal. Franc., p. 338.

[2] Theobald, Rec. G. S. I., X, p. 43.

[3] It appears at first sight, also, to be in direct opposition to Dr. Falconer's conclusions, but a study of his writings leaves it doubtful whether he ever expressed any decided conviction on the subject. He repeatedly noticed the close connexion between some Siwalik

would therefore be put forward with very little confidence if it were not supported by some stratigraphical data. As the approximate age of the Siwalik rocks is a necessary element in any argument founded upon their fauna, it will be best to shew how the stratigraphical evidence supports the view that these beds are of pliocene and not of miocene age, before proceeding to notice some other interesting points of connexion between the Siwalik and other faunas, recent and extinct.

Stratigraphical evidence of age of Siwaliks.—The stratigraphical data as distinguished from the purely homotaxial relations just discussed depend entirely upon the connexion between the typical Siwaliks and the Manchhar beds of Sind. The position of the latter has been already described in Chapter XIX,[1] where it was shewn that the whole of the Manchhar group, comprising, where thickest, but little less than 10,000 feet of strata, rests upon the miocene Gáj group, the age of which is determined by the far more satisfactory data afforded by marine organisms, and is shewn to be more probably upper than lower miocene. The lower Manchhar beds pass down into the Gáj rocks, so that it is reasonable to believe that no difference of age of any importance exists between the two. It has also been shewn that the mammalian fauna of the lower Manchhars, although containing several species in common with the Siwaliks, is altogether older in aspect; and that the majority of the forms hitherto recognised belong to the peculiar types of even-toed ungulates allied to *Merycopotamus* and *Anthracotherium*, intermediate in character between pigs and ruminants, and peculiarly characteristic of the miocene epoch. In these lower Manchhar beds also there is found a form of *Dinotherium*, another miocene type unknown in the Siwaliks proper, though found (the species being distinct) in the beds of Perim Island. Now, there can be no reasonable doubt that the Manchhar beds of Sind, as a whole, correspond with the Siwalik formation of Northern India; for the two are portions of one continuous band of upper tertiary rocks, and, viewed in this light, the relations of the faunas are very striking, the fossiliferous lower beds of the Manchhar group corresponding to the unfossiliferous Náhans, and

forms and those now found in India, and appeared for a long time (Pal. Mem., I, p. 28) rather disposed to consider that the tertiary mammalia of India "lasted through a period corresponding to more than one of the tertiary periods of Europe" than to class the Siwalik fauna with the miocene of Europe. In his later writings he certainly spoke of the Siwalik fauna as miocene, but only incidentally; whilst in some of his latest papers he argued in favour of man having been a probable contemporary of *Colossochelys* and the Siwalik mammalia—an idea which it is difficult to reconcile with the miocene age of the fauna.

[1] See *ante*, p. 466.

the almost unfossiliferous upper Manchhar beds to the ossiferous strata of the Siwaliks. It has already been shewn how extremely difficult it is to trace particular zones amongst the confused and contorted mass of the newer tertiary deposits in the Sub-Himalayan ranges and the Punjab; but, so far as the evidence extends, it is certainly in favour of a close correspondence between the Manchhars and the Siwaliks, the upper Siwaliks being represented in Sind by the conglomerate, less fully developed there than to the northward, at the top of the series, whilst a large proportion of the lower Manchhars is made up of the grey sandstone, so well developed in the Náhan group. If, therefore, the lower Manchhars of Sind are upper miocene, so is the Náhan group of the Punjab; and it is impossible, either on stratigraphical or palæontological grounds, to class the fossiliferous middle Siwaliks lower than pliocene, the upper Siwaliks, which contain *Bos* (*Bubalus*) *palæindicus*, being probably upper pliocene. Briefly stated, the evidence is that the Siwalik fauna is newer than the Manchhar fauna, and found in higher beds, and the Manchhar fauna is not older than upper miocene.

Survival of miocene forms in Siwalik beds.—If the views expressed in the preceding paragraphs be admitted, it will be seen that we have represented in the Siwalik beds a pliocene fauna, containing an abnormally large miocene element; and although the presence of this older element may be partially due to an undetected admixture, by the collectors, of fossils from lower beds, it is certain that this explanation will not suffice to account for all the older types of Siwalik mammals; for the locality and horizon of several typically middle tertiary forms, such as *Dorcatherium*, are well known to be middle, or even upper Siwalik. An admixture of European miocene forms, though to a much smaller extent, is found in the older pliocene of North America. There is, however, a good reason for believing that European miocene forms survived to a later period in India than in Central Europe, because several genera not known in beds of later age than the miocene of Europe are found living, or are represented by nearly allied forms, in the tropics of Asia and Africa. It has even been suggested that of the two most important faunas in the tropics of the Old World, the Indo-Malayan (exclusive of that inhabiting the Indian peninsula) and the Ethiopian, the former is allied to the lower or middle miocene, the latter to the upper miocene of Europe.[1] Thus in the miocene beds of Central Europe, besides a monkey very like *Semnopithecus*, there

[1] Fraas, Württemberg'sche naturw. Jahreshefte, XXVI, 1870, p. 297; v. Pelzeln, Africa-Indien, Verh. Zool. Bot. Ges. Wien., 1875, p. 61; and Ueber die Malayische Säugethier-fauna; Festschrift, 25 Jahr. Zool. Bot. Gesellsch., 1876, p. 19; Wallace, Geographical Distribution of Animals, I, pp. 114 to 124.

are found two genera of apes, *Pliopithecus* and *Dryopithecus*, allied to the gibbons (*Hylobates*) of Assam, Burma, and the Malay countries; there is an insectivore nearly affined to *Tupaia* (Indian and Malay), and forms of deer closely resembling *Cervulus* (another Indo-Malay genus) occur, besides the living genera *Viverra*, *Rhinoceros*, and *Tapirus;* the two latter, however, being also found in European pliocene beds.

Pliocene fauna of Pikermi in Attica.—There is, however, one European fossil fauna which is of singular interest from its resemblance to that of the Siwalik beds. In this collection of extinct mammalia, which has been discovered at Pikermi in Attica,[1] not only is there a remarkable admixture of typically miocene forms with other species which have a later aspect, but there is the same remarkable abundance of true ruminants as in the Siwaliks. In the miocene strata, although ruminants occur, they are in general but little, if at all, superior in number to the other artiodactyle ungulates; but in the Pikermi beds there are 15 ruminants to one pig and one *Chalicotherium;* in the Siwalik fauna, 28 ruminants and but 15 other artiodactyle ungulates. Another point of similarity in the two faunas is the absence of small mammals.

The following is a list of the genera found in the beds of Greece, with the number of species belonging to each genus:—

PRIMATES—
Mesopithecus, 1.

CARNIVORA—
Simocyon, 1; *Mustela*, 1; *Promephitis*, 1; *Ictitherium*, 3; *Hyæna*, 1; *Lycyæna*, *Hyænictis*, 1; *Machærodus*, 1; *Felis*, 4.

PROBOSCIDEA—
Mastodon, 2; *Dinotherium* 2.

UNGULATA PERISSODACTYLA—
Rhinoceros, 3; *Acerotherium*, 1; *Leptodon*, 1; *Hipparion*, 1.

UNGULATA ARTIODACTYLA—
Sus, 1; *Chalicotherium*, 1; *Dremotherium*, 2; *Antilope*, 3; *Palæotragus*, 1; *Palæoryx*, 2; *Tragoceras*, 2; *Palæoreas*, 1; *Antidorcas*, 1; *Gazella*, 1; *Camelopardalis*, 1; *Helladotherium*, 1.

RODENTIA—
Hystrix, 1.

EDENTATA—
Ancylotherium, 1.

Of birds, a *Phasianus*, a *Gallus*, and a *Grus* have been identified: of reptiles, bones of *Testudo* and *Varanus*. Of the above 30 genera of mammals, 13, besides *Helladotherium*, which is said to be scarcely distin-

[1] Gaudry: Animaux fossiles et geologie de l'Attique.

guishable from the female of *Sivatherium*, are found in the Siwaliks of India: besides this, the fauna bears in many respects the same similarity to that of Africa at the present day as the Siwalik mammals bear to their living Indian representatives. Now, this Pikermi fauna is constantly quoted as upper miocene, and its connexion with the miocene beds in other parts of Europe is unmistakable, no less than 15 species being undistinguishable from those found in various miocene deposits. Several of these species are doubtfully identified, but amongst the number are such characteristic forms as *Machærodus cultridens, Mastodon turicensis*, and *Hipparion gracile*. But, as M. Gaudry points out in the clearest manner,[1] the ossiferous beds of Pikermi contain at their base, and below the horizon whence the bones have been obtained, a layer with pliocene marine fossils, and all the beds containing the bones, together with the pliocene marine beds, rest unconformably on lacustrine miocene rocks. There can be therefore no reasonable doubt that the Pikermi fossils, like the Siwaliks, are of pliocene age, and that the quotation of them as miocene is an error.[2]

Migration.—The points of similarity between the European miocene faunas and the animals now inhabiting either tropical Asia or Africa south of the Sahara may be due either to migration and survival[3] in a more favourable climate, or to the fauna having been formerly more uniform over large areas, and to the modified descendants continuing to live in one region, whereas they have died out and been replaced by distinct types in other parts of their old province. On the latter hypothesis we may suppose that the fauna of Central Europe and Malayasia was more or less uniform in the lower miocene period, and that Greece and Africa formed a single zoological province in pliocene days; but that the gibbon-like apes, *Tupaiadæ* and other Malay types, died out in Central Europe, and the giraffes, antelopes, &c., in Greece, whilst the descendants of their relatives survived in the Malay countries and Africa respectively. The theory of migration presents, on the whole, fewer difficulties, and is rather

[1] Tom. cit., pp. 426-435.

[2] For the theory adopted by M. Gaudry to account for the survival of these miocene animals in pliocene times, see "Animaux fossiles et geologie de l'Attique," p. 431. It appears simpler to believe that the miocene fauna of Europe migrated to the southward, and that many species survived in Greece after they had died out north of the Alps. Hence the admixture of pliocene and miocene types.

[3] It is assumed in the present and in other arguments employed in this work that similarity of organisation implies relationship of descent, *i. e.*, that animals having similar structure are descended from the same ancestors more or less remotely. The theories of evolution and of origin of species by descent with modification are now so widely accepted amongst naturalists that it is unnecessary to explain or defend them.

in accordance with the little we already know of the Indian miocene (Manchhar) fauna, in which living tropical forms appear to be less represented than they are in the deposits of that age in Europe. It is not unreasonable to suppose that some of the forms named, and especially the ruminants, migrated into Southern Asia at the close of the miocene period.

Effects of change of climate.—It is true that amongst the marine invertebrates there is a well-marked resemblance between the miocene genera of Europe and living tropical forms. The Indian and African land faunas of the early and middle tertiaries are as yet too imperfectly known for any comparison to be made between them and those of the same epoch in extra-tropical regions. It is not improbable that there may prove to have been a greater similarity than exists amongst the terrestrial forms living at present, and it is also probable that if such similarity existed, it will be found to have consisted mainly in the greater richness of the extra-tropical fauna in middle tertiary times, and in a number of types now extinct or confined to the tropics having been represented in both tropical and extra-tropical zones of climate. This last probability is founded on the fact that the temperature of Europe in the miocene epoch was in all probability nearer to that of the present tropics than to the temperate climate of recent times, and that consequently whole families of animals, and of plants intolerant of cold, then ranged to much higher latitudes than they now do. That this was the case with plants is shewn by the well-known miocene (or eocene?) flora of Greenland, Spitzbergen, and Alaska,[1] and by the species found in such marvellous abundance in the miocene beds in Central Europe.

It is by no means an improbable inference that the representation of so many European miocene genera in the Indian Siwaliks is due to changes caused by the gradual refrigeration of the earth in later tertiary times, and to the migration of the fauna towards the tropics. There is good reason for believing that Europe and South-Eastern Asia were connected by land after the eocene period; and as it is certain that a great portion of the disturbances affecting the Himalayan strata are of pliocene or post-pliocene date, it is reasonable to conclude that at the close of the miocene epoch no such mountain barrier as exists at present separated the Indian peninsula from Central Asia. There is independent evidence in favour of the view that the elevation of the Tibetan plateau is of post-Siwalik date; for remains of *Rhinoceros* and other large mammals occur

[1] Heer: Flora fossilis Arctica, Vol. III, Pt. 4, &c.

at an elevation of 15,000 feet in Tibet,[1] and it is not probable that these animals lived in so elevated a region.[2]

Comparative poverty of recent mammalian faunas.—But the immigration of the European miocene forms may not be the only way in which the Siwalik fauna was affected by the secular refrigeration of the earth's surface, culminating in the glacial epoch. It is true that there is a considerable amount of similarity between the Siwalik fauna and that of India at the present day; but, nevertheless, there is a very striking distinction—a distinction due less to change and replacement than to disappearance. Even after making allowance for the fact that the whole assemblage may not have existed contemporaneously, there is nothing so striking in the fauna of the Siwalik epoch as the wonderful wealth and variety of forms. It must be recollected that we know little or nothing of the smaller mammals, and that animals of size inferior to a pig or a sheep are scarcely represented. It would be premature to infer that, as at the present day, the more minute forms exceeded the larger types in abundance; for the conditions of intermediate ages may have affected the more bulky animals far more than the minute *Rodentia*, *Insectivora*, *Chiroptera*, &c. Still it is only reasonable to suppose that the ancestors of the present *Micro-mammalia* lived in the same profusion as they do now; and it is incredible that the living rodents and insectivores can play the parts on the modern stage and fulfil the functions of the great ungulates and carnivores of past times. Comparing like with like, and especially passing in review the *Carnivora*, *Proboscidea*, and *Ungulata*, all represented, and all, except the *Proboscidea*, well represented in the living fauna of India, indeed better than in most other parts of the world at the present day, it is impossible not to be struck with the comparative poverty in variety of the existing mammalian types. We have of course but an

[1] There is, on the other hand, a probability that the elevation of the great plateau of Central Asia dates from a period prior to the glacial epoch, or at least antecedent to the close of the cold period, because, in the first place, there are numerous signs of ice having formerly occupied a much greater area than it does at present; and secondly, there is a very remarkable change in several species of migratory birds between the forms found in Western India (many of which are common to Europe) and those found in Eastern India and Burma, many of which are peculiar to Eastern Asia. The two groups meet in India; and although stragglers are found to the east and west of the limit, they are not common. The contrast is easily explained if the breeding places of the representative races have been separated for ages through the elevated regions of Central Asia being so covered by snow and ice as to be unfitted for birds, and especially for insectivorous birds, to breed in. Amongst examples of the representative races, *Motacilla alba* (v. *dukhunensis*) and *Erythrosterna parva* of Western India, replaced by *M. luzoniensis* and *E. albicilla* to the eastward, may be quoted.

[2] Falconer, Pal. Mem., I., p. 173.

imperfect knowledge even of the larger Siwalik animals, and remains of *Carnivora* are rare, so much so that probably many species remain undiscovered; but even at present the known Siwalik carnivores are more numerous than the living forms of similar size in the same area, and the ungulates exceeded their living representatives in number in the proportion of more than 5 to 2, there being 50 known Siwalik species and only 18 recent. The superior wealth of the older fauna is both generic and specific; not only are the types more varied, but there is a greater variety of forms in many of the genera; thus 6 species of *Rhinoceros* existed where now there is only 1, or, including Eastern India and Burma, only 3; and no less than 11 extinct elephants and mastodons are represented by a solitary living form. Even such modern types as *Bos* have dwindled in numbers from 6 to 2.

This great impoverishment of the recent mammalian fauna is not peculiar to India. It is found in other parts of the Old World and in America, wherever remains of animals have been preserved in sufficient quantities amongst the deposits of the later tertiary epochs for a good idea of the fauna to be presented. In the words of Mr. Wallace, "we live in a zoologically impoverished world, from which all the largest and fiercest and strangest forms have recently disappeared;" and he makes the happy suggestion,[1] that this enormous reduction in the numbers of the greater mammals is due to the glacial epoch. Thus for a second time we find the action of this great physical change reflected in the Siwalik fauna; and we have an addition to the arguments urged in the sixteenth chapter[2] in favour of India having been affected by the cold period which immediately preceded the present day.

The post-pliocene Narbada fauna is very poor compared with the Siwalik. It is true that the former comprises two species of elephants and two of hippopotamus; but only two bovines have been detected, one deer, and one antelope. This difference may be partly due to imperfect knowledge, to the much smaller range, both in area, and in time as represented by thickness, in the case of the Narbada beds; but none of these circumstances can possibly account for the whole distinction; for large collections of Narbada bones have been made, and more ruminants would surely have been detected, had many existed. It is probable that the Narbada fauna is posterior in date to the main operation of the agency, whatever it may have been, that caused so many of the Siwalik mammals to die out. The further diminution in the numbers of *Proboscidea*, and the complete disappearance of the genera *Hippopotamus* and *Rhinoceros* from Central

[1] Geographical Distribution of Animals, I, p. 150.
[2] *Ante*, p. 372.

India, may perhaps have been partly due to the agency of man, who, if the evidence of the chipped quartzite implement already mentioned [1] can be trusted, must have been a contemporary of the Narbada fauna.

Relations of Siwalik to Perim Island fauna.—Before quitting the subject of the relations between the Siwalik and other fossil faunas, two other Indian deposits containing mammalian remains require notice, besides the miocene beds of Sind and the Punjab, and the post-pliocene formations of the Ganges valley and the Indian peninsula. These two deposits are those of Perim Island in the Gulf of Cambay, the known species from which locality have already been quoted [2] and are marked P in the preceding list of tertiary fossil vertebrates, and those of the Irawadi valley in Upper Burma marked I.

The known mammals from Perim Island comprise ten species, of which four, viz., *Mastodon latidens, M. perimensis, Acerotherium perimense*, and *Sus hysudricus*, are common to the Siwalik beds. All these forms are, however, found in other fossil faunas; *Mastodon perimensis* and *Sus hysudricus* being met with also in the lower Manchhar beds of Sind, *Acerotherium perimense* in the Irawadi deposits, and *Mastodon latidens* in both, so that all the forms common to Perim Island and the Siwaliks are clearly species of wide range. The absence of *Elephas* and its sub-genera, and of bovines, and the presence of *Dinotherium*, tend strongly to make the Perim Island fauna appear of greater age than the Siwalik generally; but, on the other hand, the presence of so highly specialised a genus as *Capra*, if the generic determination be accepted,[3] the occurrence of *Camelopardalis* and *Antilope*, and, above all, the absence, so far as is known, of any of the *Anthracotheridæ* and other older ungulate types so abundant in the miocene beds of Sind and the Punjab, are opposed to the idea that the Perim Island rocks can be of higher antiquity than pliocene. They possibly occupy an intermediate position between the Siwaliks proper and the Manchhars of Sind, but they are more nearly allied to the former.

Comparison with Irawadi fauna.—It will be necessary to revert to the mammalian remains found in the Irawadi valley when describing the rocks of Burma. All that it is now necessary to point out is that, although the proportion of species identified with Siwalik forms is rather less than in the case of Perim Island, only four species, viz., *Stegodon cliftii, Mastodon latidens, Acerotherium perimense*, and *Merycopotamus*

[1] *Ante*, p. 386.

[2] *Ante*, p. 343.

[3] It should not be forgotten that *Capra perimensis* is founded solely on a frontlet with the horn-cases, and that nothing is known of the greater part of the cranium, the teeth, or the limb bones. See Lydekker, Pal. Ind., Ser. X, 3, p. 83-170, Pl. xxviii, fig. 4.

dissimilis, out of thirteen, being known to be common to the Siwaliks and the Irawadi beds, the general facies of the two faunas is very similar. Both contain a considerable proportion of living genera unknown in the middle tertiaries of Europe, together with some older forms, such as *Acerotherium* and *Merycopotamus*. The Irawadi fauna perhaps may be equivalent to upper Siwalik.

The Tibetan mammalian fauna[1] already noticed is too imperfect for comparison.

Comparison of Siwalik and recent faunas.—Lastly, a few words may be added as to the points of connexion between the Siwalik fauna and that now found in India, Malayasia, and Africa. The most remarkable distinction between the mammalian life of tertiary times and that of the present day, the comparative wealth of the former and poverty of the latter, has already been noticed; but it is matter of some interest to trace how far the Siwalik types are represented by animals now inhabiting India, and how many of the tertiary genera, though still living on the earth's surface, are no longer found in the regions formerly inhabited by their Siwalik allies. As the fauna of India varies in different parts, it will be best to take for comparison with the Siwalik mammals all forms now existing in the Indo-Gangetic plain, from the Indus to the parallel of Calcutta, together with those inhabiting the lower slopes of the Himalayas up to 4,000 or 5,000 feet. This area comprises portions of three distinct zoological sub-provinces, the animals inhabiting the Indo-Gangetic plain to the westward exhibiting some distinctions of importance from those occurring to the eastward, and the lower slopes of the Himalayas having a very different fauna, distinguished by the presence of numerous Malay types. In this comparison, again, the minor generic or sub-generic groups of many modern naturalists are not enumerated; *Rucervus*, *Rusa*, and *Axis*, for instance, being considered merely forms of *Cervus*, and *Bibos*, *Bubalus*, &c., of *Bos*. The following is a list of the Siwalik genera represented by species living in Northern India,[2] the number of such species being added :—

PRIMATES—

Semnopithecus, *2*; *Macacus*, *1* (or 2).

CARNIVORA—

Felis, *8*[3]; *Hyæna*, *1*; ***Canis***, (including *Vulpes*), *4*; *Ursus*, *1*; ***Mellivora***, *1*; ***Lutra***, *2* (or 3).

[1] Falconer, Pal. Ind., I, p. 173; Strachey, Q. J. G. S., 1851, p. 292.

[2] The living genera are taken chiefly from Jerdon's Mammals of India, a few alterations and additions being made.

[3] Five of these are of small size.

PROBOSCIDEA—
Elephas, 1.

UNGULATA PERISSODACTYLA—
Rhinoceros, 2 (both only found to the eastward, and the second species barely within the area) ; *Equus*, 1 (also barely within the area, but to the westward).

UNGULATA ARTIODACTYLA—
Sus (including *Porculia*), 2 (or 3) ; *Cervus*, 4 ; *Antilope* (including *Gazella*), 2 ; *Bos*, 2 ; *Ovis*, 1 (in the Punjab only). *Capra* is not found living in the area named, but 3 species exist on the higher Himalayas, and two on the hill ranges to the west of the Punjab.

RODENTIA—
Mus, many species ; *Rhizomys*, 1 (only found to eastward) ; *Hystrix*, 2 (or 3).

The genera of *Ungulata* now found in Northern India and not represented, so far as is known, in the Siwalik fauna are only four : *Cervulus*, *Portax*, *Tetracerus*, and *Nemorhedus*. Some twelve genera of living Indian and Himalayan *Carnivora* have not been found in the Siwalik rocks, but all are of comparatively small size ; *Viverra*, *Arctictis*, *Cuon*, and *Paradoxurus* being the largest.

The Siwalik genera not now living in Northern India, but still existing elsewhere, are *Meles* and *Camelus*, now confined in the wild state to the palæarctic region, and *Hippopotamus* and *Camelopardalis*, both surviving in Africa. All the other living forms already enumerated are common to India and Africa south of the Sahara, except *Semnopithecus*, *Macacus*, *Ursus*, *Cervus*, *Ovis*, and *Rhizomys*, whilst *Hyæna*, *Canis*, *Mellivora*, *Equus*, *Antilope*, and *Ovis* are unknown in the Malay regions. The genera common to the Siwalik fauna and Malayasia, but not found in Africa, are *Semnopithecus*, *Macacus*, *Ursus*, *Cervus*, and *Rhizomys*. The first two and the last of these are, however, represented by allied forms in Africa, whilst no such near Malayan representatives of any of the Siwalik-African forms, except *Canis* (replaced by *Cuon*), can be mentioned. It may be added that of the twelve genera of living Indian *Carnivora* unrepresented in the Siwaliks, the majority are Malayan forms inhabiting the Himalayas. It is clear that the Siwalik fauna resembles that now inhabiting Southern Africa more than it does the assemblage of living *Mammalia* now found in Malayasia, and it is probable that this resemblance is due to both the pliocene Siwaliks and the recent Ethiopian faunas, together with a very large proportion of the animals now inhabiting the plains of India, being descended partly or wholly from the same ancestors, and perhaps from their ancestors having originally migrated southward from the miocene lands of Central Europe and Asia. We know nothing of the miocene mammals of Southern Africa, but such information as we possess of the

upper miocene fauna of Northern India renders it probable that most of the Siwalik mammals emigrated about the close of the miocene epoch, and a portion of the descendants of the Siwalik immigrants may have inhabited the country ever since. Many forms have, however, died out, and it is probable that in comparatively recent times some of these extinct forms have been replaced by Malayan types, either introduced from the eastward, or spreading northward from the singularly isolated Malayan faunas now inhabiting the Malabar coast and the Southern Indian hills. Many, however, of the forms which at first sight appear to have distinctly Malayan affinities, such as *Cervus* (*Rucervus*) *duvaucelli* and *Bos gaurus*, despite their close alliance with living Malay forms, and the want of related species in Africa, are probably descended from Siwalik ancestors, and are not Malayan immigrants. Again, in a few cases, as in that of the Indian gazelle, some of the species which, judging by their range and their close connexion with forms inhabiting other countries, are amongst the most recent additions to the Indian fauna, come from the west and not from the eastward.

CHAPTER XXV.

EXTRA-PENINSULAR AREA.

LOWER HIMALAYAS.

Limits — General features — The terminal area — Classification of rocks — Correlation of groups — The gneissic series — The slate series — The Simla slates — The Blaini group — The Infra-Krôl — The Krôl group — The relation of the slate and gneissic series. Special metamorphism and disturbance — Trappean rocks — The Chor mountain — South-east of Simla. Kumaun and Gharwál. Nepál. The Sikkim area — Darjiling gneiss — The Dáling series — The Damúda series — Relations of the three series — The Bhután border: Baxa series — The Dikráng section. SUMMARY.

Limits.—The name "Lower Himalaya" does not spontaneously suggest the area to which it is here restricted. This is not a mountain-zone of medium elevation, continuous between the Sub-Himalayas and the Central or Tibetan region; for, as already stated (p. 557), we find the tertiary rocks in the Kángra district within a mile of a lofty ridge of "central gneiss," on the prolongation of the main Himalayan axis, and structurally belonging to the Tibetan region. Still, to any one who knows the ground, the character "Lower" would suggest the area in question; for the ridges of the Dhauladhár and Pir Panjál, belonging to the Central Himalayas, and overhanging the Sub-Himalayan zone in the north-west, are much more lofty, rugged, and persistent than the mountains of the Lower Himalayas, occupying the broad area, some 50 miles wide, between the great snowy range and the plains.

To the east this feature continues beyond the range of exploration, in the mountains north of Assam: on the west it ends, or begins, abruptly very nearly on meridian 77° E., a short distance west of Simla. Both the Biás and the Sutlej flow from east to west across this terminal boundary of the Lower Himalayan region, while the Tons and the Jumna are the first rivers having a southerly course in this ground. The mention of these rivers shews that the meridional watershed of India occurs here; but this is a fact of no significance; for it is possible that almost within historical times the Jumna may have flowed westward, instead of to the Ganges.[1] Simla stands on the Sutlej-Jumna watershed, and, as

[1] See page 417.

a well-known place, its name has been given (p. 529) to this terminal region of the Lower Himalayas. If a politico-geographical name were required for the Lower Himalayan region, the kingdom of Nepál would furnish the most suitable, as it occupies the whole middle area for a length of 500 miles; and the Gurkhas of Nepál formerly held sway to beyond the Sutlej.

General features.—The character chosen to designate this region of the mountains is a superficial one; yet it is an index of important structural peculiarities: the low general average of elevation is due to the irregularity of the disturbance that has affected the rocks, without producing any dominant lines of dislocation or of upheaval; being thus in marked contrast with two other divisions of the mountains, where steady outcrops are determined by continuous parallel axes of flexure and of dislocation. There is, no doubt, a very decided prevalence of a strike parallel to the general mountain-axis, and the dominant dip of the strata is towards that axis; but local interruptions are so frequent, that the general result, as brought out by the drainage courses, is more like that from the denudation of a homogeneous mass. It has been suggested [1] that the present rivers cross this area on lines of fracture; but observation lends no support to the opinion: the drainage channels, great and small, are as devious as they could be worn through a promiscuous mass of broken materials. A possible cause for this condition will be suggested.

The boundaries of the Lower Himalayas are, however, well defined. On the north, so far as known from the west end, there is the great gneissic axis, with constant granitic intrusion, forming the main snowy range. On the Sub-Himalayan border, along the "main boundary" of the tertiary zone, there is also, from the west up to Nepál, some approach to constancy in the older rocks. They are intensely contorted, but with more steadiness of direction than in the interior of the area; although still there are numerous breaches of regularity, as at the sharp bends of the main boundary east of Dehra, and again just east of the Ganges, both of which coincide with twists in the strike of the slates. This circumstance (the local strike of the strata at these points) is perhaps an additional argument in favour of this boundary being primarily a feature of denudation, or at least against its being a great master-dislocation (p. 540).

Regarding the distribution and structure of the rocks in the Lower Himalayas, our information is still more scanty than in the case of the Sub-Himalayas, and our description must be correspondingly bare. For a

[1] Q. J. G. S., VII, p. 309.

length of 500 miles in Nepál, we have only notes upon one short section in the middle; and to the east of this, throughout the whole range, only one narrow area has been examined, in Sikkim. It is in the north-western portion that most observations have been made, and it is there that the rocks are in the most favourable condition for study, as exhibiting least metamorphism. This is apparently due to the position being a sub-terminal one in the mountain area. However this may be, we find here a continuous broad belt of unaltered limestones and shaly slates at the edge of the mountains; and at many points they extend far into the interior. This border contracts gradually to the eastwards, being comparatively narrow, though still well marked, at Naini Tál; but on the Kathmándu section it has disappeared, and in Sikkim gneissic rocks come very close to the southern or main boundary. The relation of these unaltered rocks to the gneissic series is the chief puzzle of the Lower Himalayas. The boundary of the two is as irregular as it can be, and quite unlike any feature described in other Himalayan regions.

As in the case of the Sub-Himalayas, and for analogous reasons, we must describe the Lower Himalayas in sections of areas, commencing at the west end, with the terminal area already denoted as the Simla region.[1]

The terminal area.—It is important to note at starting that the termination of the Lower Himalayas, in about 77° of east longitude, is strictly a feature of the general mountain-structure, the boundary there being more or less homologous with that elsewhere. The several rock-series of the area do not continue with their general north-westerly strike up to the terminal boundary, nor end there along a transversely denuded outcrop, against the tertiary formations. Here, as elsewhere, the strike of the old rocks conforms to the main boundary, even when almost at right angles to the axis of the range; and the same external band of unaltered palæozoic rocks intervenes continuously between the gneiss of the interior and the fringing tertiary formations. This condition holds good for the whole Western Himalayas, the strata forming throughout an independent system of disturbance: at no point along the mountain border on this side do the gneissic rocks touch the Sub-Himalayan zone, so they can never (in, or since, silurian times) have been continuous with the crystalline rocks of peninsular India. This fact would be almost a corollary from the statement already given (p. 569), that the contortion of the slates is of post-nummulitic date; it may now be quoted as a confirmation of that statement.

[1] For some particulars of this ground, see Mem. G. S. I., III, Pt. 2, 1864; and Rec. G. S. I., X, p. 202, 1877.

Classification of rocks.—The following petrographical groups are distinguishable in the Simla Himalayas. It is convenient to consider them as two series, although they may be in part equivalent; the relation between the two being the great puzzle of the geology of this region, and the chief contrast between it and the Central Himalayas.

A—Outer, newer, or slate series—	
Król: limestones, sandstones and shales . . .	800—1,200
Infra-Król: shales (often carbonaceous) and flags .	1,000—3,000
Blaini [1]: limestone, sandstone and conglomerate .	100
Infra-Blaini (Simla slates): slates and flags . .	over 5,000
Base not known.	
B—Inner, older, or gneissic series—	
Gneissose schists	6,000
Massive gneiss	100—600
Schistose gneiss	?

Correlation of groups.—The absence of fossils is one of the most puzzling facts connected with the geology of this area, and the same remark applies to these formations throughout their extension on the southern face of the Himalayas, eastwards to Nepál and westwards to the Jhelum. All the rocks of series A are such as might be expected to contain organic remains; they are fully exposed to view at some much frequented localities, as in the hill stations of Mansúri (Mussooree) and Naini Tál, and on the road to Simla,—at all of which many skilled observers have searched carefully for fossils, but in vain. Only one authentic case of organic remains from these rocks is on record:[2] some indeterminable casts of bivalve mollusks from a band of limestone in the Tál, or Bheng, river, at the end of the Dehra Dun, east of the Ganges.

In the absence of fossils, an attempt at identification can only be made through comparison with sections of known rocks, or by continuous connexion with known sections. On the former grounds, the following conjectural affiliation was made by Dr. Stoliczka, through a comparison with the rocks described by him in Spiti, beyond the snowy range due north of Simla.[3]

Simla.	*Spiti.*	*Europe.*
Król limestone.	Liláng series.	Upper trias.
Infra-Król.	——	Lower trias.
Quartzites and mica-schists at Simla.	Kuling.	Carboniferous.
Blaini.	Muth.	Upper silurian.
Infra-Blaini (Simla slates).	Upper Bhábeh.	Lower silurian.

[1] Formerly spelt "Blini": the first vowel sound is full, as in blind, so the correct spelling is "Blaini."

[2] Mem. G. S. I., III, Pt. 2, p. 69.

[3] Mem. G. S. I., V, p. 141.

On the same page (*l. c.*) Dr. Stoliczka mentions a prior recognition of the infra-Król beds as lower trias, from their being mineralogically so very similar to the Bunter Sandstein of Europe; and no remark is so frequently repeated in Stoliczka's later Himalayan notes as the resemblance of the semi-oolitic triassic limestone to the Król rock. An apparent confirmation of the age assigned by Dr. Stoliczka to the Król group was published about the same time[1] in Professor Gümbel's description of a specimen, from the Schlagintweit collection, said to have been obtained at Dharampur near Solan in the Simla district, containing three fossils, *Lima lineata* and *Natica gaillardoti*, found also in the Muschelkalk in Europe, and a new species, *Nat. simlaensis* (Gümb). In view of all the circumstances,[2] however, it seems safest to doubt the authenticity of this specimen. The well-known locality Dharampur, in the neighbourhood indicated, is certainly on nummulitic rocks, and there can be but little doubt that the specimen in question came from some totally different ground, possibly from Tibet.

The method of connected observations has suggested a different correlation of the upper members of the Simla series. These rocks, as has been said, are continuous, although locally much contracted and obscured, along the Himalayan border up to the Pir Panjál, and the limestone there occurring, like that of the Simla region, at the top of the slate series, has been satisfactorily identified by Mr. Lydekker[3] with the carboniferous limestone of Kashmir (the Kuling limestone of Tibet), and quite distinct from the triassic limestone, which also occurs in the valley. He also thinks that the infra-Król is carboniferous, leaving the Blaini group and the Simla slates to represent the Muth and Bhábeh rocks of Tibet, as silurian. In the Pir Panjál and Kashmir, as in the Lower Himalayas, these lower rocks have as yet proved unfossiliferous; but there can scarcely be a doubt of their representing the infra-carboniferous slates of Tibet in which silurian fossils have been found.

The gneissic series.—The gneissic and schistose rocks, even in the Simla region, occupy the largest portion of the Lower Himalayan area south of the great snowy range. That range, westwards from Nepál, has been described by different observers as formed of, or supported by, gneiss, with extensive intrusion of granite. In describing this gneiss between the Sutlej at Wangtu and the Bhábeh pass, north-east of Simla, Dr.

[1] Sitzungsber. bair. Akad. d. Wiss., 1865, II, p. 354.

[2] So many serious errors have been found to exist in the localities assigned by the Messrs. Schlagintweit to their reptilian and other collections, that no dependence can be placed upon any specimen collected by them.

[3] Rec. G. S. I., XI, p. 63, 1878.

Stoliczka distinguished it as the "central gneiss," asserting that, geologically speaking, it had nothing to do with the gneiss of the Lower Himalayas to the south of it.[1] It is presumable that there was some better ground for this opinion than the presence of an eruptive rock in the gneiss along this mountain axis; but however this may be, it has been shewn beyond reasonable doubt by Colonel McMahon[2] that the crystalline series forming the peaks south of Wangtu, of which the Simla watershed is an offshoot, is the same as that of the main range.[3] The massive granitoid gneiss which, although subordinate, is the most conspicuous member of the series, and thus was unfortunately made its representative member, passes into the north base of these southern peaks above Sangla on the Baspa (which joins the Sutlej south of Chini), at an elevation of about 10,000 feet; and it emerges on the south base at Lorot (20 miles due south-west from Sangla) at the head of the Pabar valley, at an elevation of about 8,500. In the intervening mountains of Bisáhir, crossed by the Borendo and Rupin passes, the stratification lies flatly, and there must be some 6,000 feet of the gneissose schists overlying the more granitoid rock. Although no granite has been observed here, these are no doubt the same as the schistose gneiss, having a high northerly dip, described by Dr. Stoliczka in the Bhábeh section (*l. c.*, p. 14) and distinctly included by him in his "central gneiss." The opinion that this gneiss was restricted to the main mountain axis was, no doubt, a principal reason for the name given to it, which is certainly not altogether appropriate to the real state of the case. "Lower gneiss" would have been a better designation for it, as it is probably the oldest rock in the whole Himalayas. In the Tibetan region we shall find gneiss that is probably an altered silurian rock; whereas the junction of the Lower Himalayan gneiss with the silurian slates on the north side of the main range is represented as abrupt, if not unconformable; although the granite is said to penetrate even up to the overlying secondary rocks.[4]

This determination of the Lower Himalayan gneiss in the Simla region to be the same as that of the main range, is a point of great importance; as it at once disposes of the conjectures that had been hazarded, as to its being possibly of later age than the Król rocks; and it is only fair to suggest that those conjectures may have influenced

[1] Mem. G. S. I., V, p. 15.

[2] Rec. G. S. I., X, pp. 216—221.

[3] It should be recollected that Dr. Stoliczka did not himself survey the Simla region, and that his examination of the gneiss in this part of the Himalayas can only have been of the most cursory description.

[4] *l. c.*, p. 12.

Dr. Stoliczka's decision upon the distinctness of the two gneisses. Supposing the massive band of granitoid gneiss to have an approximately fixed position in the series, as is implied for this area by the foregoing observations, it will be of great service in tracing the position of the gneissic series and its relation to the slate series. On the secondary ridge, and principal watershed, running west-south-west from the Bisáhir peaks to Simla, this gneiss forms the crest at Hatu (10,469); and it is very prominent below the crest in the southern branch, forming the Shankan ridge, from which it passes eastwards into the valley of the Pabar. A low east-north-easterly dip is the general lie of the gneiss in this position. Hatu would seem to be on the crest of an anticlinal, and 8 miles to the north, in the Sutlej (3,000), the same gneiss, or what we are supposing to be the same, forms the banks of the river from Kamársen bridge, nearly to Rámpur, the capital of the Bisáhir State. North of the Sutlej, in the Jalori ridge, running from the snowy peaks of Kulu west-south-westwards to the Cheru summit (10,134), within 12 miles of the tertiary zone, a massive granitoid gneiss again occurs, with a prevailing low easterly dip.

All these gneissic rocks of the interior are continuous with the crystalline mass of the main chain; and the principal feature to notice about them is their small disturbance as compared with their state in that chain, or with the condition of the newer rocks forming the outer zone of the Lower Himalayas. But there is one mass of granitoid gneiss differently circumstanced in the Simla area, forming the Chor mountain (11 982 feet high), 25 miles south-east of Simla, and 20 miles from the main boundary at Náhan. Lithologically, the rock forming the Chor is the same as the massive gneiss of Hatu and elsewhere, but in the first-named mountain it is quite surrounded by the rocks of the upper series. It will be described further on.

The slate series.—Although true slaty cleavage, distinct from lamination and jointing, is of rare occurrence in the Lower Himalayas,[1] the prevailing type of rock in the newer series, indicated on p. 595, is that best described as slaty; and it will be convenient to speak of these rocks collectively as the slate series, as distinguished from the lower metamorphic series. Locally, the texture is below this standard of induration, and the rock is rather shaly than slaty, as in the Infra-Król shales at the base of the Król mountain. Locally also, and more frequently, crystalline foliation is well developed, where the rock is rather schistose than slaty, as in those same Infra-Król shales on Jako at Simla.

[1] Mem. G. S. I., III, Pt. 2, p. 72.

The normal order of this series is nowhere so surely displayed, with so little disturbance and alteration of the strata, as in the Simla region, just inside the Sirmúr rocks of the standard area, on the main road to Simla. From the Solan rest-house the Król mountain (7,406) on the north, the Bój on the west, and Kanój on the south-east, are within easy walking distance. They are formed, above the road level, of massive limestone, more or less isolated upon a base of earthy slates, thus leaving no doubt that the limestone is the latest of the series. The Blaini stream rises just west of Solan; and in its channel the small, but highly distinctive, group that bears its name is repeatedly exposed, sometimes in contact with the nummulitic clays. Considering its persistent small dimensions, this Blaini group has a remarkably wide distribution, having been traced in typical form as far as the Król limestone itself; and thus a much-needed horizon can be recognised in an immense thickness of rocks that could scarcely otherwise be separated, and a clue is furnished whereby to unravel and delineate the very complicated disturbance to which these outer rocks have been subjected.

So far as can be, or at least has been, made out in the outer zone of the mountains, there is conformity between the several groups of the upper series; but in discussing the relations of the two series, facts will be observed involving the overlap of the upper groups at or about the Blaini horizon.

The Infra Blaini rocks (Simla slates).—In the neighbourhood of Solan, where the three upper groups of the slate series are typically seen, the Blaini rocks occur in the lowest ground, so the underlying formations are not exposed. These may be well seen near Simla, below the Blaini outcrop on the east in the valley of the Ussan, and on the north towards the Sutlej. They consist of finely laminated slaty shales and thin sandy flagstones, with occasional beds of earthy sandstones. The lamination is sometimes fine enough and the induration sufficient to produce serviceable roofing slate, but much inferior to true cleavage slates. From the Blaini rocks at the Lakri Bazaar there is an apparently unbroken succession of the Simla slates to Náldera (the ridge above Bassantpur), where the limestone of the Sutlej valley begins; the dip is steady, and there is no trace of a flexure; 5,000 feet is a low estimate of the thickness of such a section. The limestone just mentioned is supposed to be the Król limestone, brought down by faulting; and, as in every other known section, the actual substratum of the Simla slates has not been observed in this region.

The Blaini group.—This group consists of two very distinct members, each of which seldom exceeds 50 feet in thickness, and is generally much less. The upper rock is a fine, compact or micro-crystalline

magnesian limestone,[1] of pale-grey and pink tints, thin bedded, but often amalgamated into a single mass. It rests upon a quartzite sandstone, often a clear quartzose rock, but sometimes rusty and more or less earthy. In whole or in part this lower band is very often highly conglomeratic, with well-rounded pebbles and small boulders of white quartz and variously-tinted quartzites, and sometimes partially-rounded debris of slate rocks. Pebbles of crystalline rocks have not been observed in it in this region. Although often crushed together, mixed and inverted, these two rocks seem never to have been interstratified originally; and it is possible, notwithstanding their so constant association, that they were considerably separated in age. The persistent occurrence of two thin bands of such different types of rocks over so large an area is a remarkable circumstance, but a most fortunate one for the geologist who undertakes the study of this difficult ground.

Infra-Krol group.—This is a provisional form of nomenclature, and it is not improbable that "lower Król" group would be more appropriate; but until the connexion can be based upon palæontological facts or more extended observation of the strata, it is safer to adhere to the more vague expression of the relation. At the base of the Król, north of Solan, the soft black infra-Król shales are very well exposed. The carbonaceous element is the most striking character of the group, but it cannot be adopted as an essential one, or even perhaps general. Sometimes this character extends down to the beds overlying the Blaini limestone, as in the outcrops on the Ghambar between Kiari Ghát and Sairi; but often it is wanting in beds that seem to belong to this horizon, as along the Solan watershed, on the crushed anticlinal between the Król and the Bój. In the absence of faulting, or of an outcrop of the Blaini limestone here, all the beds should belong to the infra-Król group, but they are not carbonaceous. It may perhaps be questioned whether this can be attributed to a subsequent removal of the carbonaceous ingredient, or to an original inequality of distribution. This carbonaceous ingredient of the shales is, however, very widely spread, being well seen at Mansúri (Mussooree), and other places at a distance from the Simla region. The shiny black crushed rock, so common in faulted ground in this region, is presumably derived from the carbonaceous beds of the infra-Król group.[2]

[1] McMahon: Rec. G. S. I., X, p. 210.

[2] *Subathu Coal.*—The coaly aspect of this carbonaceous shale, especially where made glossy in crushed ground, has often raised expectations of finding coal. In 1862, Colonel Fyers, in spite of warnings, made an attempt at mining upon an outcrop of this crushed rock near Subáthu, expecting to find coal to the deep. The stuff contains sometimes as much as 25 per cent. of fixed carbon, besides 11 per cent. of volatile matter, partly hydrocarbons.

In the neighbourhood of the Król or at Simla, a thickness of about 1,000 feet would include the beds between the Blaini limestone and the base of the Król group; elsewhere there is a much greater apparent thickness, as from the base of the Tára Devi quartzite at Mán Ghát summit, to the outcrop of the Blaini group in the Ussan, where the thickness would seem to be 3,000 feet. But in all these sections the strata are greatly affected by small slips; and these interfere with any attempt to estimate the dimensions of the groups, and tend either to exaggerate, or to diminish the true thickness.[1]

The Krol group.—On the Król mountain, from which it takes its name, the top group consists almost entirely of limestone, a pale-grey compact or crypto-crystalline rock, sometimes dark and locally oolitic; but even here there are subordinate shaly beds, sometimes pale pink, and at the base there is a variable band of clear coarsish quartz sandstones. The calcareous element is decidedly the prevailing character of the group, as compared with the underlying slate series, which is remarkably deficient in this ingredient. The sandy element, however, is often very prominent. As an expansion of the bottom band, this fact is well exemplified at Simla, in the massive quartzites of Boileauganj, and of Tára Devi ridge to the south, overlaid by a remnant of the Król limestone at Jutog. Elsewhere, as south of Guma peak in Sirmúr, the limestone itself is rather a calcareous sandstone, or occurs as subordinate bands in a mass of sandstone. When the ground comes to be worked out, these variations will be useful, as suggesting local conditions of deposition; and the establishment of this character in the standard area will facilitate conjectural identification of the group elsewhere, as in Nepál.

The relations of the slate and gneissic series.—No special account has been given of the distribution of each group, nor of the structural features of the ground, because the little that is known of either will be fully exhibited in discussing the difficult question of the relation of the two rock-series. The structural peculiarities of the Lower Himalayas are best shewn by contrast with those of the other regions of the mountains. All the boundaries hitherto noticed were determined along what are clearly Himalayan lines of disturbance. Even in the middle region, where both the bottom tertiary and middle tertiary junctions were shewn with some probability to be aboriginal, *i. e.*, primarily (as junctions) lines of deposition, these had previously been determined as lines of erosion by the early results of Himalayan disturbance. In the North-West, again, where the Sub-Himalayan and Central Himalayan features come together, there is complete correspondence between the structural features in the

[1] Mem. G. S. I., III, Pt. 2, p. 37.

gneissic axes of the Dhauladhár (the range just north of the Kángra valley) and the Pir Panjál (the range south of Kashmir), which are constructed on the same pattern as the latest ridge of the Siwaliks. The change is immediate where, at the east end of the Dhauladhár, the Lower Himalayan region begins: the boundary of the slate and the gneissic series here does not run even approximately parallel to the main boundary; it bends east and then north, round the point of a ridge of gneiss, up the valley of the Biás towards Sultánpur, and thus all round the basin of the river and its tributaries to the south, where it runs to south of west along the Jalori ridge of gneiss, separating the Biás from the Sutlej, and then round the point of this ridge and along its south flank to far up the valley of the Sutlej.

Other changes are commensurate with this remarkable one in the outline of the boundary: from being a single narrow outcrop along the base of the Dhauladhár, the slate and limestone series spreads into a wide area (some 20 miles by 30) in the Biás basin, and similarly on the Sutlej. The structural features in the two positions are equally discrepant: along the Dhauladhár the strata are vertical, or underlie towards the gneissic axis in *inverted order;* whereas in the great river basins of this terminal area of the Lower Himalayas, the confused contortion of the rocks within the basin is beyond description; but at the boundary the dip on all sides is towards the overhanging ridge of gneiss, and in *normal order,* the [illegible]l limestone being uppermost.[1]

[illegible]ce is as if the slate and limestone series really passed benea[illegible]s, and were older than it; but if this gneiss is the same as tha[illegible] the[illegible] range, such a view would be untenable. The suppositio[illegible]ich[illegible]ld best represent the facts to the imagination is, that these de[illegible]nd [illegible]pitous valleys in the gneiss had existed in pre-silurian, or at lea[illegible]re-ca[illegible]iferous times, and had become filled with deposits of those [illegible]ods. [illegible]ler subsequent compression the disturbance would principall[illegible]ake ef[illegible] upon the softer later deposits, and in a manner corre[illegible]ding [illegible] the features described. It is doubtful indeed whether a[illegible]ther sup[illegible]tion will fit the case: the structural features may almo[illegible] said to [illegible]ncompatible with the view of their formation by faulting[illegible] inversion,[illegible]oduced by lateral thrust upon any parallel sequence o[illegible]strata, the [illegible] different results of which processes are so well illustr[illegible]d in neighbourin[illegible] areas.

An appa[illegible]ntly complete refutation of the objection just stated, against the explana[illegible]ion by faulting, is found in the Sutlej basin. The Sháli mountain (9,420′), which forms such a picturesque object in the land-

[1] Mem. G. S. I., III, Pt. 2, p. 50.

scape from Simla, is formed of limestone, and it stands within the special basin of disturbance in question. Above and east of the gap connecting the Sháli with the watershed-ridge east of the Sutlej, there is an outcrop of the Blaini group, dipping north-eastward; and from the Sháli the limestone passes to the south-east, and round the head of the valley under Thiog, Fágu, and Mahásu, into the Náldera ridge, where, we have already seen (p. 599), it apparently passes southwards under the base of the Simla slates. Thus on the south side the rocks of the Sutlej valley behave towards the slate series of the typical area, as they do to the gneiss on the north side; and it would seem that the crucial evidence, whereby to judge the whole case of these valleys full of the latest beds of the series, were to be found here, where the horizons of the contiguous rocks are more comparable.

The question turns upon the point, whether the limestone of the Sháli, and of the Sutlej and Biás valleys, is the same as the Król rock; and, so far as our observations go, the answer is in the affirmative. The general resemblance of the two rocks is sufficiently marked, and the differences are no greater than have been observed in the Król rock within its standard area. Carbonaceous beds also are found in both of those valleys; and in one case an outcrop of the Blaini group has been marked, north of the Sutlej, on the spur north-west of Bihul; where, in contact with a broad dyke of trap, there is a small thickness of coarse quartz conglomerate, overlaid by slate and thin-bedded limestone.[1]

Accepting this identification, we are then bound to suppose a dislocation and downthrow of great magnitude in the Sutlej valley, or an upheaval of the ground at Simla and to the west of it. The Blaini outcrop north of Simla passes westwards along the flank of the ridge to Dhamini, where it turns south and then south-east, following a devious course to near Haripur on the old road to Simla.[2] Thus the form of this inevitable dislocation is quite on a par with that of the boundary with the gneiss between the Sutlej and the Biás. We cannot, however, reasonably apply this crucial evidence all round, without consideration of the objections already noted. We have seen how regularly even the oldest rocks can conform to the lines of Himalayan disturbance—a fact which implies some approach to original homogeneity of disposition in the strata so affected; and, in like manner, it seems obligatory to account for such very abnormal lines of dislocation as that under notice by supposing a

[1] Mem. G. S. I., III, Pt. 2, p. 56.

[2] For the observations here quoted, and for others to follow, as well as for a fuller discussion of this puzzling question, see Colonel McMahon's excellent paper on the Simla Himalayas, Rec. G. S. I., X, p. 204.

corresponding discordance of original relations in the masses subjected to the disturbing action. For the case in hand no supposition seems so plausible as that already made, that these upper rocks in the actual valley basins were originally laid down in similar deep hollows formed by subaërial erosion in the gneissic series; and that the dislocated upheaved mass of Simla slates, forming the ridge on the south of the Sutlej, was determined in form by an underlying original ridge of the supporting gneissic rocks. The presence of this massive gneiss in the Chor, on the axis of this curved dislocation, is perhaps some support for the explanation offered of the latter feature. This mode of action is also supported by observations made elsewhere, from which it was inferred that compression has a tendency to increase original inequalities of surface.[1]

The junction of the slate and gneiss series in this region is not, however, all of the sharply defined form described in the Sutlej valley, where the massive unaltered limestone dips abruptly towards the massive gneiss. The observation already mentioned, of the Blaini group on a high point north-east of the Sháli, and having a low north-easterly dip, gives us cause to expect that the Król rocks occur in the ascending section in the direction of the high mountains, lofty spurs from which are at no great distance. The same Blaini outcrop has been traced by Colonel McMahon to the south-east across the Thiog ridge into the valley of the Giri, east of which it passes under the Paternála ridge, formed of Król quartzites, to emerge again in the valley under Chepál, whence it is traceable to the Tons at the bridge on the Simla-Mansúri (Mussooree) road. The expectation to find the supra-Blaini rocks inside this line is natural; but the difficulty of recognising them is indefinitely increased by the greater or less metamorphism that all the rocks have undergone in this direction.

A very important first attempt to accomplish this task has been made by Colonel McMahon. He considers that the calcareous schists forming the summit north of Matiáni, on the Simla watershed ridge, east of Sháli, represent the Król limestone; and they pass on to Nárkanda, close under the Hatu summit, formed of the massive gneiss. Similar calcareous and carbonaceous rocks occur in the Sutlej valley, north of Hatu, above and below Kotgarh, and close above the massive gneiss in the gorge of the river. Other identifications have been made in like positions elsewhere, as at the base of the Shankan ridge about Kotkhai and Tirhosh (Taroche), and far up the tortuous valley of the Rupin. The degree of metamorphism these supposed Król beds have undergone is always markedly less than that of the gneissic rocks of the enclosing

[1] Rec. G. S. I., VII, p. 62.

ridges; but the action has been sufficient to amalgamate the two rocks at their junction, so that the detection of their original contact is most difficult. Such crucial sections must, however, be sought for and found, to complete the direct evidence for the proposed relations of the rocks.

Such observations as those now recorded—where top beds of the slate series rest close upon the massive gneiss—imply, not only the removal of the 6,000 feet of schistose gneiss, normally overlying the massive rock in closely adjoining positions, but also the entire overlap of the Simla slates by the Król deposits in the inner area of the mountains; thus completing the picture of the primitive condition of the Simla area—as a great mass of gneissic rocks, deeply eroded by atmospheric denudation, and gradually submerged beneath the palæozoic waters. The idea of the upper gneiss being the Simla slates converted, is hardly to be thought of; a much more probable equivalent for the infra-Blaini beds being found in the silurian slates resting upon that gneiss in Tibet.

Special metmorphism and disturbance.—The extent to which the top beds of the slate series have been locally metamorphosed under different circumstances is well exhibited at Simla itself; the garnetiferous and hornblendic mica schists, with abundance of vein quartz, forming Jako, being undoubtedly converted infra-Król beds, overlying the Blaini group, which is well seen round three sides of the mountain. This feature is in itself most interesting, as shewing that advanced results of metamorphism are brought about independently of any plutonic heat; the Simla slates underlying these highly foliated schists of Jako shew no sign of crystalline metamorphism, although of course they must have had the full benefit of any heat from below that can have been instrumental in producing those effects on the upper rocks. This remarkable case of special metamorphism at Simla was a strong point in the suggestion that even the gneiss of Hatu and elsewhere might really be a later formation than the Król beds, which at so many points seem to pass under it. That suggestion did not necessarily imply that the Król beds maintained their unaltered condition beneath the gneiss; but the proof (p. 597) that this latter rock is the same as the infra-silurian gneiss of the main range, renders the suggestion altogether untenable.

In this connexion notice may be taken of a common structural feature of the hills in this region; how, almost invariably, vertical or highly contorted beds are found in the bottoms of the valleys, whether transverse or longitudinal; while in ascending the slopes the dips become lower, and at top the beds are often quite flat. The usual explanation of this would be that, as the valleys are the result of denudation, erosion had taken place where the strata were most crushed. A quite

opposite interpretation of the facts has been suggested by Colonel McMahon, to shew that more or less of the contortion of these rocks has occurred since the hills and valleys assumed somewhat of their present form:—that, lateral pressure, set up beneath a deeply eroded surface, would take effect in the manner described, crushing the strata in the positions of least resistance, the action being distributed in a diminishing degree up the sides of the hills. Some confirmation of this view may be derived from the fact that great contortion, the result of lateral pressure, has been proved to have taken place in the outer hills since the main features of the Lower Himalayas were carved out (p. 570); and it is by no means unlikely that at the same time some action of the kind supposed occurred in that area.

There is always a risk in applying characters that are obscure, to modify the interpretation of characters that seem plainer; but in complex questions no suggestion should be omitted. Thus the fact that on a commanding summit, some of the highest beds of the whole stratified series are found in a high state of metamorphism, overlying unaltered rocks, and well removed from the area of general metamorphism, seems decidedly at variance with certain views put forward, on page 569, regarding pre-tertiary Himalayan land and the late disturbance of the slate series. The risk here lies in the imperfection of our knowledge regarding the processes of the metamorphism of rocks; but on any supposition, short of some innate form of metamorphic action at this spot, we must connect the fact with the principal disturbance and crushing to which these rocks have been subjected; and it must have been a form of disturbance very different from that suggested in the last paragraph. The same considerations would suggest that, at the time of their metamorphism, these rocks on Jako, and the valleys on both sides, must have been covered by a thickness of deposits of which no account has yet been taken. Or may we reverse the reasoning, and take the fact of the rocks being altered on this peak as a proof of how very superficial a matter thorough metamorphism may be?

Trappean rocks.—The distribution of eruptive rocks in the Simla region is not without its bearing upon the foregoing considerations. On the best known section, that along the road through Simla to Nárkanda, only one thin dyke has been observed near the latter place; whereas in the same rocks of the adjoining area in the Sutlej valley, and again in the basin of the Biás, we find profuse trappean intrusion, evidently connected with the extreme crushing and disturbance the slates and limestone have undergone in those positions; and the same intrusion occurs again freely to the south-east, under like conditions. Trap is rare

in the gneissic series, unless in particular spots, as on the Sutlej between Nogli and Rámpur; and its absence in the slates in the area indicated may be due to an underlying mass of gneiss, such as has been just suggested to account for the peculiar form of dislocation connected with the elevation of that area.

This distribution of the trap, connected with the fact that the slates had not been contorted when the Subáthu deposits were laid down (p. 569), has been taken[1] to prove that the trap of the Lower Himalayas must be at least of post-nummulitic age. That it should so very rarely penetrate the tertiary rocks is rather remarkable (p. 557). Can the explanation of this apparent anomaly be, that the origin of this intrusive rock is rather innate than hypogene?[2]

The Chor mountain.—The most conspicuous summit of what we may still speak of as the Simla region is the Chor mountain, having an elevation close upon 12,000 feet (11,982). It stands between the Giri and the Tons rivers, 25 miles south-east of Simla, and as near to the plains as that station itself. Throughout the whole Lower Himalayas no summit of this elevation is known to occur so near the edge of the mountains. The entire crest is formed of the most massive granitoid gneiss, which, unless repeated by faulting or flexure, must be here at least 5,000 feet thick. The area occupied by this rock is about 10 miles long, from south-east to north-west, by 6 miles broad; it is surrounded by the slate and limestone series.

At first sight, and from the point of view of the slates and the metamorphic series forming an approximately conformable sequence, the feature was most puzzling, as it had to be accounted for in some manner as a protrusion of the basal rock through an enormous thickness of overlying deposits; and accordingly it was so accounted for[3]; a partial resemblance of the cross-section to that of the Dhauladhár was allowed to overrule many almost incompatible facts recorded at the same time,[4] and the Chor was presented as a protruded mass. All the observations we possess of the ground are few and incomplete; but they seem to agree best with the view brought forward by Colonel McMahon, that the Chor was already a mountain in palæozoic times.[5] The ground offers an accessible and compact field for the study of this most interesting question of the relation of the two great rock-series.

[1] Mem. G. S. I., III, Pt. 2, p. 71.

[2] For a parallel case, see Mem. G. S. I., VII, (201)—(203).

[3] Mem. G. S. I., III., Pt. 2, p. 47.

[4] *l. c.*, pp. 41 to 45.

[5] Rec. G. S. I., X, p. 211.

The gneiss of the Chor is highly granitoid and massive. It is certainly generally free from foreign rock, but vein granite has been observed in it.[1] The bedding and foliation can, however, be traced, indicating a low dip to north-north-east; and other features shew this to be the lie of the gneissic mass: on the north, the overlying schists reach farthest up the spurs, and the gneiss farthest down the stream beds; while on the south the highest outcrops of the gneiss area are on the spurs and the schists extend up the valleys. This latter disposition requires that the gneiss to some extent overlies schists; but it has not been made out whether this is by normal superposition, or by inversion of newer beds, or by deformation of an original junction, or by faulting.

On the supposition of this gneiss being protruded from below among the slates, whether in a partially plastic state or by faulting, its neighbourhood should be a position of special disturbance. The contrary is certainly the rule. In ascending from the Giri to the Chor, the Simla slates maintain a moderate dip towards the mountain; they become gradually metamorphosed, and about Banálah and Soháua, close to the gneiss, soft hornblendic garnetiferous mica schists, like those of Jako, are nearly horizontal. Similar beds on the north side form the spur between Mándera and Surán, where they rest upon the porphyritic gneiss. If these beds are indeed of the infra-Król group, the case of overlap and complete unconformity would be established. On the south-east side of the Chor the limestone is in great force, and the disturbance is more marked.

South-east of Simla.—Although the fullest and clearest sections of the upper groups of the slate and limestone series are found in the Simla region, the most complete case of removal of these beds occurs in the same ground; west of the Król, up to Arki, the great Król limestone is wanting, unless it is represented by the narrow band at Kakarhati, on the old road to Simla, the pseudo-organic markings in which rock have often led to a vain search for fossils. The absence of the limestone here is apparently connected with the faulted elevation to the west, described on page 603. South-eastwards from the Król the limestone range is very conspicuous, being sharply defined on the north by a great faulted anticlinal that passes from Kandah Ghât, at the north base of the Król, down the deep valley of the lower Giri. From the confluence of the Palar with the Giri the limestone crosses to the north, and spreads over a large area east of the Chor, to the Deoban mountain (9,347′) in Jaunsár. The boundary with the gneissic series has not been traced

[1] McMahon: *l. c.*, p. 221.

in that direction. Along the ridge at Mansúri (Mussooree) the Król limestone occurs frequently, as on the Abbey and Camel's-back summits. On the top of Landour it is mixed with sandstones, and appears again by itself on the Tapuban point. The Blaini limestone and conglomerate are well seen on the flanks of the Sirkanda summit, and again in the Ganges at its confluence with the Hinnalgár. Intrusive trap is not uncommon in the slates at Mussooree.

Kumaun and Garhwal.—As the earliest British possession in the Himalayas, the province of Garhwal and Kumaun was the first open to systematic observation. Indeed, the first attempt at official geological survey work in India was the mineralogical survey of this ground, undertaken by Captain Herbert by order of the Governor General (Lord Hastings). The work was finished in 1825, but was not published till 1842,[1] nine years after the death of Captain Herbert. As the work of an accomplished man, fairly versed in the science of his day, Captain Herbert's report is of permanent interest for students of geology in India, as the best local illustration of the state of geology at that time.

A quarter of a century later it was again on this ground that a connected geological survey on a large scale was undertaken by Captain Richard Strachey, of the Bengal Engineers, now General Strachey. His map includes the same area of the Lower Himalayas as Captain Herbert's, between the Sutlej and Nepál, with the important addition of a broad band in the Tibetan region. A comparison of the two works gives an instructive illustration of the advance made by geological science in the interval. With some few exceptions, our remarks on this portion of the Lower Himalayas are taken from General Strachey's observations.[2]

The section through Naini Tál and Almora presents some analogies with the Simla section. The ridge at Naini Tál is a great synclinal range, with many local fractures and contortions, like its type the Król range. The great limestone that forms many of the summits to the south of the lake is very like the Król limestone; and the pink, greenish and dark-grey shaly slates associated with it shew the same affinities. A conglomerate like the Blaini rock has been observed in the dark slates forming the ridge north of the Kota dún. One observation, indeed, has been recorded throwing doubt upon this correlation: the Messrs. Schlagintweit announced[3] the discovery "in the clay-slates in the neighbourhood of Naini Tál of numerous *Foraminifera*, evidently identical

[1] As an extra number of Vol. XI of the Journal of the Asiatic Society of Bengal. The map to illustrate the report was issued with Vol. XIII, 1844.

[2] Q. J. G. S., Vols. VII and X, 1851 and 1854.

[3] J. A. S. B., XXV, p. 118.

with those which accompany the eocene nummulitic formation." It is possible that these explorers may have hit upon a remnant of the Subáthu beds, folded up in the slates, like those mentioned in the Sirmúr area (p. 534), and the one case east of the Ganges (p. 535); but it is also possible that the oolitic or other concretionary forms, common in the limestone at Naini Tál as at the Król, may have been mistaken for fossils. Numerous careful observers have searched the rocks in vain to verify the Messrs. Schlagintweit's discovery.[1]

North of the limestone range there is a great dislocation with upheaval to the north, as at the Król. But in Kumaun, at least on this section, the line of fracture is filled with a basic eruptive rock, numerous dykes of which occur in the range about Naini Tál. It is apparently on the south-eastern continuation of this main intrusion that the igneous rock which penetrates the sandstones of the Sub-Himalayan zone (p. 542) is described as taking the form of a granite.[2] It is stated that the limestone occurs again to the east of this great line of intrusive rock.

North of the dislocation the contrast with the Simla section is most marked: we come at once upon thorough metamorphic strata, genuine schists, like the older series of the Simla region, rather than like any known metamorphic condition of the slate series. The strata maintain a steady, moderate north-easterly dip, thus presenting a very marked decrease of disturbance as compared with the newer rocks. This was also a point of contrast between the two series in the Simla region. In Kumaun, too, trap rock is comparatively rare in the gneissic series. South of Almora (the capital of Kumaun) a broad band of granitic rock occurs in the schists, and has a considerable range to south-east and north-west. It seems to be in the main a massive granitoid gneiss; but some true vein granite occurs with it. Mica schists occur again north of the granitoid rock, containing strings and nests of impure graphite, the north-easterly dip being continued; after a space the same beds turn up, with a south-westerly dip. North of the synclinal there is a marked line of disruption, with copious intrusion of trappean rock and the introduction of new strata—slates, conglomerates, and quartzites, with limestone in force. Disturbance is, again, more varied and more marked in these formations, and it is not unlikely that they may ultimately be identified with the slate and limestone series of the Simla region, though no specific attempt can now be made at affiliation. Beyond these, again,

[1] There is also a possibility, as in the case of the triassic limestone, said to have been found by one of the same collectors near Solan, and in numerous examples amongst their zoological collections, that there was a mistake about the locality of the specimen.

[2] Q. J. G. S., 1851, VII, p. 298.

there is a region of crystalline schists at the base of the great snowy range.

Nepal.—From the borders of Kumaun we have to pass by a blank of 250 miles to get our next glimpse at the rocks of the Lower Himalayas, on the Kathmándu section.[1] The length of this section is about 30 miles, from the main boundary; which distance would nearly take us to the second line of dislocation and intrusion north of Almora in Kumaun, and as far as Nárkanda in the Simla section. Except in the conjectural identification of the formations, the features are unlike those described in the western area.

The first rocks seen north of the tertiary sandstone are some earthy schists, having a crushed dip of 50° to north-by-east, quite parallel in strike to the sandstone and to the boundary. A thin band of blue limestone occurs in these beds; and further on, a thick band of black schistose slates, in which are some irregular layers of impure coaly matter. All these beds, though decidedly sub-foliated, are less altered than any rocks to the north of them, and also less highly inclined. After some special contortion and folding, connected with which a doubtfully intrusive trappoid rock was observed, the schists are succeeded by a broad band of quartzites; and these again by a great mass of white crystalline limestone, all dipping at 70° to 80°, to north by east. A specimen of this rock proved to be not dolomitic.

This great band of limestone would seem to end the ascending section; for over a broad area on the north this limestone and the quartzite are repeated in broken confused masses, as if in a synclinal flexure, forming the most wild and picturesque portion of the Rápti valley, below Nimbua Tanr.

The resemblance of this series to that of the Król and infra-Król rocks, is quite sufficient to warrant the supposition of their connexion; and even the form of the section, so far, is homologous with the corresponding portion of the western sections. The greatly advanced metamorphism and the excessive disturbance are the chief points of contrast.

At the head of the Rápti valley, about Bimphédi, there is an abrupt change of the strike, to north-35°-west, in flaggy quartzose schists; and in the Chessagarhi ridge these rocks are associated with thick bands of porphyritic gneiss, which becomes dominant at the north base of the ridge. On this side the change is abrupt, from the gneiss to a great series of flaggy and slaty schists occupying the Pinauni and Chitlong valleys. The dips are in opposite directions in the gneiss and the schists close to their junction, suggesting that the gneiss had been faulted up

[1] Rec. G. S. I., VIII, p. 93.

along a broken anticlinal. With slight variations, there is a steady ascending section of the flaggy schists up to the Chendragiri ridge, overlooking the valley of Nepál; and here again we come upon calcareous rocks, which occupy the whole width of the Nepál valley. It is a broad synclinal, with repeated minor compressed flexures of these upper rocks. Pure limestone occurs chiefly towards the top of the series, as the white crystalline rock at the summit of Phulchók (9,720′) and elsewhere; but there is a great thickness of strata, in which the calcareous element is subordinate, the prevailing variety being a massive, very fine, schistose quartzite, with only a small percentage of carbonate of lime.

It is not a very forced supposition to conjecture that these Nepál rocks are the same as those south of the Chessagarhi ridge, and represent the Król series. The change of composition is even analogous to that observed between the Król and the ground at and north of Simla. The flaggy schists of Chitlong would fittingly represent the Simla slates.

Crystalline schists rise again, more or less vertically, on the north-north-east side of the valley, apparently in descending sequence with the calcareous formation, and at first alternating with the coarse, felspathic gneiss forming the lofty Sheopuri ridge. To the north-west, slaty schists come in again at the inner base of the Sheopuri ridge, and have a decided southerly underlie towards the gneiss. In the valleys of the Tádi and Trisulganga the strike of these schists changes to east-north-east, and calcareous rocks occur with them. The Sheopuri gneiss probably does not cross the Trisulganga.

It is doubtful whether the gneiss of the Chessagarhi or Sheopuri ridges represents the old gneiss of the western sections. Its structural relation to the schist and limestone series is quite different. No granitic vein-rock was observed in connection with it. It is also noteworthy that no trappean eruptive rock occurs in these sections, except in the doubtful case already mentioned near the main boundary, although the rocks are so universally contorted. The fact is apparently adverse to the conjecture hazarded (p. 607) upon the quasi-innate nature of trap in the western region.

The Sikkim area.—Passing over another reach of forbidden ground, 250 miles long, in Eastern Nepál, the Lower Himalayas are again accessible in Sikkim, and we find an immense change in the aspect of the rocks. There is no calcareous group, and all the rocks are more or less metamorphic; but their arrangement is very different from that seen in the Kathmándu section, and superficially more like that of the Simla region.

The first observation of importance in this ground was the discovery by Dr. Hooker, in 1849, of rocks containing fossil plants of the Damúda formation at the base of the Sikkim hills.[1] This still remains the only case of identification between the pre-tertiary rocks of peninsular India and of the Lower Himalayas; and while we are shut out from observation in Nepál, nothing can be done to follow up this clue towards a fuller correlation of the formations in the two areas.

In 1874, Mr. F. R. Mallet was deputed to examine the ground with a view to the possible discovery of useful coal-seams in the Damúda rocks. Several seams of workable dimensions were found, but the strata have been subjected to such compression and contortion, that the coal is everywhere reduced to a flaky crumbling state, so that it could only be used after artificial consolidation. The broken condition of the rocks would also make mining very difficult. Mr. Mallet has, however, given a description of the rocks that deserves careful attention.[2] His observations extended along the fringe of the hills through the Western Bhútan Duárs to the Sankos river, near longitude 90°; but as there is a striking contrast in the rocks to east and west of the Jaldoka, forming the boundary of Sikkim on the east, the descriptions had better be given separately.

The Sikkim area is more than 90 miles long, from the Mechi on the west, at the Nepál frontier, to the Jaldoka on the east. The Tista (Teesta) river, flowing from the great snowy range, divides this area about equally into the Darjiling division on the west and the Dáling on the east. North of Darjiling lies the broad and deep valley of the Rangit; while the Tista and the Rangchu form a similar deep depression north of the Dáling area, the combined effect being that of two broad lofty spurs confronting each other on opposite sides of the lower gorge of the Tista.

There are three series of rocks within the area specified: a gneissic series, forming the whole of the mountain masses above 2,000 to 3,000 feet in elevation, and called the Darjiling gneiss; a great thickness of schist and slate, called the Dáling series, extending not only along the outer border of the mountains, but up the gorge of the Tista and round into the valleys of the Rangit and Rangchu; and the Damúdas, forming the third series of the Lower Himalayan rocks in Sikkim. The last-named are only found at the outer edge of the mountains, their greatest inward extension being a short way up the valley of the Tista, where of course the deepest section of the rocks occurs. The Damúda outcrop dies out within the limits of the Sikkim border: on the west it

[1] Himalayan Journals, Vol. I, p. 402.
[2] Mem. G. S. I., XI, Pt. 1.

cannot be traced beyond the Bálásan river, 4 miles short of the Nepál frontier. To the east it has not been with certainty traced beyond the Chel, south of Dáling, one of the positions already noticed where the tertiary rocks have been totally removed or concealed. The Dáling slates at this point form a promontory, reaching quite up to the usual line of the outer edge of the tertiary zone.

The Darjiling gneiss.—True gneiss is the preponderating rock of the gneissic series, but it often passes into gneissose schist and mica schist; bands of quartzite occur rarely, and hornblendic rocks are extremely uncommon; limestone or dolomite is unknown, and the gneiss is quartzose and never granitoid. Almost the only accessory minerals are kyanite, schorl, and garnet. Several of these characters distinguish this gneiss very decidedly from the gneiss of the peninsula, which is well represented close to the Himalayan border in the hills of Lower Assam. Except for the absence in Sikkim of the massive granitoid band, the Darjiling gneiss would fairly represent the gneiss of the Simla region. No observer in Sikkim has suggested the presence of two gneissic series. In the snowy range near Kanchinjinga Dr. Hooker has described this rock as penetrated by granite veins; but this, as we have remarked (p. 597), gives no grounds for its separation. The age of the gneiss in the great range of the Eastern Himalayas has not been proved; but there is no presumption that it is different from the infra-silurian gneiss in a corresponding position to the north-west; and thus there is a decided presumption against the Darjiling gneiss being formed of strata of the secondary period, as it must be if its apparent relation to the other formations is the true one. At the same time, the rocks of the two areas have never been examined by the same observer.

On the main northern road through Darjiling the gneissic area is 16 miles across, and the strata have the form of a broad flat synclinal, with numerous minor internal foldings. On the eastern slope also, over the Tista, the dip is inwards (westerly). A like arrangement is observed in the gneiss of the Dáling spur.

The Daling series.—Pale-green smooth slates or clay-slates are the prevailing rocks of the Dáling series in its lower outcrops, next the Damúdas; but sometimes, in this position, they are quite schistose. Darker bands occur, also some flaggy quartzites, and rare beds of hornblendic schist, which is sometimes calcareous or dolomitic; but the almost complete absence of lime is a character of the series. Beds of carbonaceous or graphitic schist are occasionally found in the Dáling series, as on the road above Pankabári, and a little south of the cart-road at Kurseong. West of the Máhánadi the beds next the Damúdas are more

earthy and arenaceous, and a slaty conglomerate occurs near, or at, the boundary. On approaching the gneiss there is always a marked increase of metamorphism. In the outer (southern) sections this apparent passage into the crystalline series is comparatively rapid; while in the interior the metamorphism of the slates near the gneiss is more pronounced, more gneissose beds appearing in them; so that the distinction of the two series is less marked.

In both the Darjiling and Dáling areas, the dip of the slates is constantly towards the gneiss, thus conforming regularly to the converging dip described in this rock, and thus completing the appearance that the Dáling series normally underlies the gneiss in a continuous transitional sequence. Only for a portion of the boundary north of Darjiling, in the Little Rangit and on the Takvor spur, an appearance of faulting between the two series was observed. From the recorded arrangement of the rocks, it appears as if the lower gorge of the Tísta lies in a broad tranverse anticlinal curve of the strata.

The Damuda series.—In some sections, as on the cart-road to Darjiling, the Damúdas have undergone little or no alteration, and their resemblance to the regular Gondwána coal-measures is very marked. The sandstones, as a rule, are rather fine-grained; they sometimes occur in thick masses, but coarse, white, felspathic sandstones of the Barákar type are not common; the beds are occasionally calcareous, and conglomerates are absent. In these characters they resemble rather the upper measures of the Damúda coal basins. The fossils as yet found comprise two species of *Glossopteris* (one is *G. browniana*), *Vertebraria*, an equisetaceous stem referred to *Phyllotheca*, and *Sphenophyllum speciosum*. Frequently, however, the Damúda rocks exhibit as much alteration as the contiguous Dálings, as west of Pankabári, and in the Rangichang east of Pankabári; the sandstones being converted into hard quartzites and the shales into dark slates and graphitic schists. In this respect, the contrast with the contiguous tertiary rocks is important; these, although greatly disturbed and compressed, never shew signs of mineral alteration.

It would be difficult to assign a thickness for the Damúda formation in this ground. The broadest section of the outcrop is at the Tísta, about one mile long; and the beds have a high dip (more than 60°) throughout, but in very various directions. The prevailing dip is inwards, towards the mountains, and almost always so near the Dálings, the stratification in the two formations being constantly parallel.

Relations of the three series in Sikkim.—The conclusions which Mr. Mallet has adopted regarding the relations of these three rock-series are: that they form a continuous stratigraphical sequence, the gneiss being

the newest and the Damúdas the oldest. This is undoubtedly the apparent reading of the recorded observations; and considered by itself, without reference to other Himalayan sections, the objection to it was more or less a theoretical one—the occurrence of a completely metamorphosed formation above absolutely unaltered deposits. Mr. Mallet did not, of course, suppose that the Damúdas passed beneath the mountain area with no greater change of texture than they exhibit at the outcrop on the edge of that area; even the Dáling slates are more schistose in the interior valleys than along the outer scarp of the mountains; still, if the apparent sequence of the rocks were true, the anomaly, on a very large scale, had to be accounted for, and the explanation of it offered by Mr. Mallet (*l. c.*, p. 42) is certainly a *vera causa*, within unknown limits, in adopting which he was much encouraged by known precedents—the thoroughly crystalline schists (*supra*-Blaini) forming Jako mountain at Simla, overlying slates that are not even sub-schistose; and, the then open question whether the Król series did not really pass under the gneiss of Jalóri and of Hatu (p. 605). The subsequent demonstration by Colonel MacMahon, that the gneiss of the Simla region is *infra*-silurian, made this latter supposition untenable; and other explanations, seemingly more far-fetched, had to be adopted for that ground, regarding the relation of the two great rock-series.

This experience in the Simla region compels us to scrutinise more closely the observations in Sikkim, and to indicate what possible alternatives there are to the view at present set forth. We have three series to deal with here, which may rather help the discussion; but we have not the advantage of knowing the normal (original) order of sequence in any of them, as was the case with the slate and limestone series in the north-west; so that in Sikkim we have no direct criterion as to inversion, or otherwise, in any particular position.

Out of all the observations recorded bearing upon this question, only one gives certain evidence upon the original relations of these formations. The opinion that the Dálings normally underlie the Darjiling gneiss is a ogether inferential, from the lie of the rocks of both series in adjoining positions, no actual section of the junction having been seen. It may, indeed, be granted that if the gneiss does overlie the Dáling series, it does so in normal sequence, inversion in this form and of such magnitude being out of the question; and this is a crucial point in the argument, for it can be said (from the evidence of our one sure section) that if the gneiss does overlie the Dálings, the Damúdas must normally underlie them, as otherwise the gneiss must be converted Damúdas, which is an untenable view.

The crucial section referred to is that in the Lehti stream (*l. c.*, pp. 28 and 39), just west of the promontory of slates south of Dáling. Here we have a continuous section showing the original relation of the Damúda and Dáling series to be complete conformity and association by interstratification, several hundred feet of each series being exposed. Nothing can shake the fact derived from this section (assuming it to be correctly described), that the two formations are conformably associated; and this disposes of one of the possible conjectures regarding the boundary—that the Damúdas were deposited against a steep bank of the slates, as is thought to be the case with the boundary of the tertiary series. The junction observed in the Lehti section may, moreover, be one of extreme chronological importance; for if the Dáling slates should be ultimately proved to be the same as the middle palæozoic slates of the Simla region, the Damúda beds so closely associated with them can scarcely be newer than upper palæozoic. The other important features of the Lehti section are, that the dip is steady and low (30°); that its inclination is to the south; and that the Damúdas overlie the Dálings. As the balance of evidence from all the other sections, and the decision regarding the slate and gneiss boundary, indicated or required that the Damúdas should underlie the Dálings, this section in the Lehti had to be considered as inverted, in spite of its unbroken low dip, and southerly inclination, which would require, or at least suggest, that the inverting thrust had been directed from the south. It is true that the Damúdas here are in their most altered condition, comprising quartzose and carbonaceous schists, with thin seams of the flaky anthractic coal; but the action of metamorphism is too capricious and untraceable to carry much weight in an argument against clear mechanical conditions.

We have already seen an instance (p. 537) in which one clear section was held valid against any amount of conflicting appearances. This Lehti section is not of the same decisive nature as the case referred to, but it certainly suggests the necessity of a close revision of the interpretation set forth for these intricate stratigraphical features. If it should be upheld as the standard section, as shewing that the Damúdas normally overlie the Dálings, all the other sections of this junction must be regarded as inversions; and the slate and gneiss boundary must be one of great unconformity or of great faulting; for, as already mentioned, it is scarcely possible that the gneiss should be converted Damúdas. This slate and gneiss boundary (p. 615) is, perhaps, the less difficult of the two, for its features are exactly similar to those in the Biás and Sutlej valleys of the Simla region (p. 602), where the fault or unconformity explanation had to be adopted. The greater difficulty is to shew how, on the

supposition of inversion, the Damúda outcrop could assume the form it has; such as, its greatest inward extension in the Tista valley, on what is taken to be an anticlinal axis of the slates. This extension on the denuded anticlinal axis is exactly what would occur if the Dálings overlaid the Damúdas normally, without inversion.

Another supposition is evidently possible: The unconformity view may be adopted, as in the North-West, for the Dáling and gneiss relation; and still the Damúdas may normally underlie the Dálings, and be altogether overlapped by these, low down (underground) on the flanks of the gneissic masses. But in this case also the section in the Lehti must be an inversion.

The reader will probably admit that the interpretation of the Sikkim sections is still an open question; and he will also recognise how very precarious any attempt must be to correlate these rocks with those of the Lower Himalayas of the North-West: the only conjectures possible are, that the Darjiling gneiss probably represents the central gneiss, and that the Dálings possibly represent the Simla slates, in which case the Damúdas must overlie them.

The Bhutan border—Buxa series.—Colonel Godwin-Austen was the first observer in this ground (1865-68); when he brought to notice [1] its peculiar features—the local concealment or absence of the tertiary rocks, and the presence in force of dolomites that are not represented in the Sikkim sections. Mr. Mallet's connected observations of the two areas were necessarily too rapid to admit of more than a suggested correlation of these adjoining and contrasting sections. The superficial view of the case (from the maps) would be, that these new rocks in the Bhútán Duárs take the place of the Damúdas in the Sikkim ground.

Mr. Mallet gave the name of Baxa series to this new formation, from the well-known Bhútánese fort which is built upon it. The fullest section given is that in the Titi stream (20 miles west of Baxa), as follows (in apparent natural order):—

(*f*).—Dark-grey slates; pyritous and rusty	300
(*e*).—Dolomite, with layers of dark-grey slate	1,500
(*d*).—Green, black and red slates, with flaggy quartzite, chloritic schist, and flaggy calcareous beds at top	1,500
(*c*).—White quartzite, locally flaggy and schistose	1,000
(*b*).—Slates with flaggy silicious and calcareous layers	800
(*a*).—Green and red slates	500

The thicknesses are only eye-estimates, the dip being pretty steady at 60°, to north-north-east. In the Jángti (3 miles east of Baxa) the

[1] J. A. S. B., XXXIV, Pt. 2, p. 106, and XXXVII, Pt. 2, p. 117.

apparent thickness of the dolomite band is 2,300 feet. Owing, however, to faulting or contortion, with denudation and concealment, this rock is locally absent from the exposed outcrop of the series, as in the space of 15 miles between Baxa and the Tursa. Carbonaceous schists were observed low in the series in the Raidak stream (10 miles east of Baxa).

Owing to the restrictions against entering the Bhútánese territory, Mr. Mallet was not able to examine the inner boundary of the Baxa series where it is fully developed, but it seems there to underlie a broad belt of slates and schists intervening between it and the gneiss, and probably representing the Dáling series. This was also observed at a point 30 miles west of Baxa, where the Baxa series ends abruptly in the surface gravels: the Dáling slates are seen in the Jángti river at a short distance off, and they seem to pass inside and to overlie the ridge of Baxa rocks. From this point to the Jaldoka at the Sikkim boundary, the hills are altogether inside the Bhútan border, and thus inaccessible.

Between the Sikkim boundary and the promontory of Dáling slates there is a short space, 6 miles long, where some of the tertiary rocks are represented; and between them and the Dáling zone Mr. Mallet found beds representing both the Damúda and Baxa series, but not in the same section. In the Mochu, on the west, just below the Dálings, dipping north-east at 60°, there are coarse and fine sandstones, shaly and slaty beds, and two or three coal-seams of about a foot in thickness. These are undoubtedly Damúdas; but the rocks below them are not exposed. At 3 miles to the east, in the Máchu, some beds, including carbonaceous layers, are obscurely seen underlying very brittle silicious flags, with pink calcareous layers, and a few of red shale, dipping north-north-west at 50°. Beyond these, and apparently overlying them, are green slates of the Dáling type. The middle beds of this section are quite of the Baxa type, and unlike anything known in the Dálings; and the carbonaceous layers at the base are not more carbonaceous than some found in the Baxa area.

Independently of any direct identification of these carbonaceous layers in the Máchu as Damúda, which would shew a distinct incipient intercalation of the Baxa beds between the Dálings and the Damúdas, and a horizontal association and transition between the Damúda and the Baxa deposits, the general comparison of the sections seem to suggest no other supposition than that these two series are in some manner representative of each other. The observations in hand do not admit of any further discussion of the question.

The Dikrang section.—After so complete a change as that from the Damúda coal-measures of Sikkim, to a great mixed series of deposits like that of Buxa, it might certainly be expected that the alteration would be permanent, and that the Buxa type of deposits would continue to the eastward; yet in the next observation we obtain of the Lower Himalayan rocks, the section is more like that in Sikkim than any other. The locality is more than 250 miles to the east of Buxa, in the Dikráng valley, inhabited by the Daphla tribes, where Colonel Godwin-Austen has described,[1] immediately inside the tertiary zone, a belt, about 1,000 feet in thickness, of dark, hard sandstones with carbonaceous shales and seams of crushed flaky coal. No fossils were secured, but the probability is strong that the group represents the Damúda formation. The beds are more or less vertical, with a north-east strike; and they are bounded on the north-west by a parallel series of white quartzitic beds with micaceous and hornblendic schists, passing by degrees into gneiss, which in turn becomes highly granitoid. Had there been anywhere near this ground any development of so conspicuous a rock as the dolomites, they would surely have been noticed by so practised an observer; so the presumption is fair that the schists next the Damúda band represent the Dáling rocks. Thus, again, the disappearance of the Baxa series and the reappearance of the Damúdas in its place, is some slight confirmation of the conjecture hazarded, that these two formations are in some manner equivalent.

Summary.—All the conclusions suggested by our study of the Sub-Himalayan rocks, and summarised at the end of Chapter XXIII, have more or less bearing upon the contiguous Lower Himalayan area, and indeed upon the whole mountain region: any additional remarks derivable from this latter area only, must refer to the earliest periods of our history, or, indeed, to pre-Himalayan time, for all the formations concerned are probably not newer than palæozoic.

From end to end of the range (very imperfectly known on the east) we have found two great rock-series, a slaty and a gneissic. For 500 miles in the middle of the range we have but one section, reaching only to 30 miles from the south border; and it is, perhaps, doubtful whether the gneiss described in that section belongs to the older series (p. 612).

In the Simla region, at the north-west termination of the Lower Himalayas, a strong case has been made out for very great unconformity between the two series, shewing the palæozoic rocks to have been

[1] J. A. S. B., Vol. XLIV, Pt. 2, p. 35.

deposited upon and against a very deeply and irregularly eroded surface of the old gneissic series (p. 605); to which circumstance may be attributed the very partial manner in which the contortion of the rocks of the Lower Himalayan area has conformed to the normal lines of Himalayan disturbance.

Structural features homologous to those of the Simla ground have been provisionally indicated in the east, in Sikkim (p. 617). Should this relation of the two series be established throughout the range, a connexion will have been made out between this peculiar Lower Himalayan region and a primitive gneissic mass, forming a fundamental nucleus for the whole series of Himalayan formations. The presence of this barrier may help in the explanation of the strange contrast presented by the fossiliferous deposits on the north, and the azoic characters of what are probably the equivalent strata on the south, even though we find that these deposits were continuously connected to the north-west.

What may have been the original southern extension of the great slate and limestone series of the Lower Himalayan area is at present a matter of pure conjecture. Considering, on the one hand, the close connexion of the Damúdas with the Lower Himalayan slates, and, on the other, the prodigious break in time between the Gondwánas and the Vindhyans of the peninsular area, it does not seem likely that the latter formation can have any representative in the newer series of the Lower Himalayan area.

CHAPTER XXVI.

EXTRA-PENINSULAR AREA.

CENTRAL (TIBETAN) HIMALAYAS.

Data available — Classification of rocks — General structure and distribution — The main gneissic axis — The Ladák axis — The Hundes and Zánskár synclinal — The Kárákoram synclinal and Kuenlun axis — The Kashmir synclinal — Position of the tertiary rocks — Gneiss of two ages — The central gneiss — Mineral character — Stratigraphical relation — Relations defined only in the middle Himalayas — The granitic axis — Terminal extensions of the central gneiss — The Zánskár gneiss — The Pir Panjál gneissic chain — The Dhauladhár gneissic range — The newer gneiss — The chief sedimentary basins. The formations of the Zánskár area — Palaeozoic series — South-west boundary — South-east boundary — The Rupshu metamorphics — North boundary with tertiary rocks—The secondary series — The tertiary series.

Data available.—As the title of this section of our work would be understood to include all of the Himalayan region not described in the preceding chapters, we must at once call attention to the small portion of that enormous area of which any trustworthy observations have been made, and of which only any notice will be taken. Of the two southern divisions of the region, the Sub-Himalayan and the Lower Himalayan, comparable sections were given, extending nearly to the eastern end of the Himalayan ranges, though with very long blank intervals. Of the entire eastern half of the central area, we have only to record Dr. Hooker's observation[1] within the frontier of Tibet, north of Sikkim and of the gneissic axis, that conglomerates, slates, and red clays were found overlying the gneiss; and further on, a dark limestone "full of encrinitic fossils and probably nummulites, but all were too much altered for determination." All the great peaks are said to be formed of granite or of massive gneiss.

On the west of the unknown area of Nepál, General R. Strachey has described the country[2] from the watershed at Lake Mánasaraur (Manasarowar), elevation 15,200 feet, in about longitude 81° 30', and has given an account of part of Hundes or Ngári-Khorsum, in the upper valley of the Sutlej, as far as the place where this river enters the transverse gorge, about Shipki.

[1] Himalayan Journals, Vol. II, pp. 156 and 177.
[2] Q. J. G. S., VII, 1851, p. 292; and X, 1854, p. 249.

This position immediately adjoins the ground of which a more detailed examination was made by Dr. Stoliczka[1] during the summers of 1864 and 1865, extending from the Sutlej to the Drás river. Neither of these descriptions extends northwards much beyond the right bank of the Indus, which river occupies a nearly central position in the region we have provisionally adopted as the Central Himalayas. For the northern portion of this ground, including the Kárákoram and Kuenlun ranges, our information is derived from the traverse made of it by Dr. Stoliczka on his journey to Káshghár in 1873-74.[2] The latest additions to the geology of the Central Himalayan region are by Mr. Lydekker in the neighbourhood of Kashmir.[3]

Thus it is seen that our materials refer almost entirely to the north-western, sub-terminal, portion of the Central Himalayas. It is in the near extension of this ground, where the main geological axes of the Himalayas seem to be more or less continuous with those of the Hindu Kush, that the battle of the mountain systems (p. 518) must be fought out. While the facts upon which the question can be decided are unknown, it is difficult to take any interest in discussing it.

Classification of rocks.—In our description of the two preceding divisions of the Himalayan region, we have been forced to depend almost exclusively upon stratigraphical characters, the rocks of the Lower Himalayas having proved unfossiliferous; and even in the tertiary Sub-Himalayan series the occurrence of fossils is so irregular, and the exact sequence of the known fossils is still so uncertain in detail, that but little use could be made of them in tracing horizons throughout so great an accumulation of deposits. Our knowledge of the Central Himalayas may almost be said to err in the opposite direction. In consequence partly, no doubt, of the explorer's attention having been especially directed to palæontological investigation, but still more as a result of the great difficulties of moving about in such rugged ground, and under such trying atmospherical conditions, our information of the central region is decidedly deficient in critical stratigraphical observations. But few will complain of this when palæontological information is forthcoming; and on this score the results already obtained are highly satisfactory. In proportion to the time devoted to this ground, the knowledge we possess of it gives a striking instance of what a master-key palæontology is in geological researches. It is sad to have to record that the master who applied that

[1] Mem. G. S. I., Vol. V, pp. 1 and 337.

[2] Rec. G. S. I., Vol. VII, pp. 12, 49, 51; and Scientific Results of the Second Yárkand Mission: Geology: Calcutta, 1878.

[3] Rec. G. S. I., 1878, Vol. XI, p. 30.

key to the geology of this region lost his life in those researches. Dr. Ferdinand Stoliczka was buried at Leh, in the very centre of the field of his achievements.

In one respect, that of the unaccountable absence or rarity of fossil remains, the slate and limestone series of the Lower Himalayas exhibit an obscure relationship to the old formations of the Peninsula; although, as regards petrological characters, the rocks of the two areas are entirely dissimilar. This azoic condition holds good for those same formations along the whole south face of the Himalayas, in their extension to the north-west of the Lower Himalayan area, along the flanks of the Dhauladhár and the Pir Panjál. It is true these rocks in that position are greatly compressed and more or less altered, but certainly not so as to obliterate all trace of fossils, had any been present in them. Already on crossing the Pir Panjál into Kashmir, fossils are found in the carboniferous limestone, sandstone and shales, which are with much probability taken to represent the upper portion of the series to the south. Still here the underlying silurian slates have as yet yielded no fossils. It is only on crossing the higher range into Tibet that the series of marine fossiliferous deposits can be fully recognised. Through this ground the geology of India can be brought into relation with the rest of the world: all the principal formations of the established stratigraphical scale, except the cambrian, devonian, permian, and neocomian, have been identified. The detailed sequence of formations will be given in connexion with the separate areas in which they were observed.

General structure and distribution.—Considering the immense range of formations—metamorphic, palæozoic, and mesozoic—represented in the sections of the North-West Himalayas, the general uniformity of distribution and symmetry of arrangement, so far observed, give much promise that, ultimately, a very complete history of the region can be made out. From end to end of the partially known ground, about 500 miles, two gneissic axes are more or less continuous.

The main gneissic axis.—The southern of these is the Himalayan range proper, of which, in Sikkim and again west of Nepál for 300 miles, gneiss is the predominant rock, many of the highest and most massive peaks being formed of it; while the slates on the north sometimes run up to an equal altitude, and the passes, through the continuous line of greatest elevation (the watershed), are generally to the north even of these slates. North of the Simla region, corresponding with the termination of the Lower Himalayan area, this main gneissic range divides into three, two of which come to an end well within the Himalayan limits; the third probably does so too, but it has not been traced so far.

The Ladak axis.—The second gneissic axis runs parallel to the first, at a distance of 50 to 80 miles. It has only been observed with any accuracy in Ladák, where it forms a steady range of moderate elevation, separating the Indus from its tributary, the Shaiok (Shyok), and the Pángkong lake. The continuation of this gneiss to the north-west would run high up on the south flank, if not to the crest, of the great Mustágh range in Baltistán, or Little Tibet. To the south-east the Ladák gneiss passes, on both sides of the Indus, through Rupshu into Chinese Tibet. This delineation includes the Rupshu metamorphics with those of the Ladák range, as they are only separated by the nummulitic trough and the tertiary axis of eruption of the Indus valley. Their possible, or even probable, distinction will be indicated further on.

The few names that have been current for the leading features of these mountains are often very inappropriate even for geographical purposes; and for geological description, they are altogether inadequate. Indeed the familiar remark, denoting the close connexion between surface features and the rocks, has a partial lithological application, rather than a geological one; for in the latter sense the idea would often be radically deceptive, as in the case before us: this gneiss of Ladák is geologically an axis of elevation; but although more steady in its course, it is less elevated than the mountains formed of much newer rocks on either side of it; it coincides in part with the actual valley of the Upper Indus. We will avoid confusion with geographical names by calling it the Ladák gneissic axis.

The Hundes and Zanskar synclinal.—Between these two gneissic axes there is a long synclinal basin in which the fossiliferous rocks are found in more or less complete sequence, according to original variations of deposition and the subsequent action of denudation. This feature is not, however, unbroken from end to end of the known ground; at long intervals the basin is more or less completely constricted or interrupted by transverse upheaval and metamorphism of the rocks. A principal break of this kind occurs where the Sutlej bends southwards at the Purgial mountain, which separates the Hundes area from that to the north-west, the secondary formations at least being completely interrupted. It was in this north-western area that Dr. Stoliczka studied the rocks, principally in the Spiti valley, at the south-east extremity of the basin, for which an appropriate name may be taken from the larger and more central district of Zánskár. The length of the basin is about 200 miles, ending abruptly east of the Drás river in a transverse mass of syenitic metamorphic rocks. The valleys of Astor and Gilgit, between which places the Indus has a north and south course, are

on the prolongation of this synclinal axis of Zánskár, beyond the crystalline rocks forming the mountains round the Deosai plateau. Nothing definite is known regarding the extension of the sedimentary series to the east of Hundes; but it is presumable, as Dr. Hooker conjectured, that the unaltered rocks observed by him north of the great gneissic range in Sikkim are more or less a continuation of those in a similar position in the North-Western Himalayas.

The Karakoram synclinal and Kuenlun axis.—North of the Ladák gneissic axis the same sedimentary series comes in again in force, but in this direction some of the upper groups of the series have not yet been identified. This area also is a broad synclinal basin, the newest rocks being found in the centre of it, in the Kárákoram ridge, and the older formations rise again to the north against a third gneissic axis, forming the core of the Kuenlun range. The direction of this range seems to be more east and west than that of the Himalayan ranges proper; so that, if the gneissic axes continued to the west, the sedimentary basin of the Kárákoram would soon be cut off in that direction; while to the east it expands rapidly.

The Kashmir synclinal.—South of the Zánskár basin, and between the diverging prolongations of the gneiss of the main Himalayan range, there is a minor synclinal basin of unaltered rocks, that of Kashmir and Pángi, divided by a transverse mass of metamorphic strata.

Position of the tertiary formations.—The one great exception to the general structural symmetry of the Himalayan formations is the distribution of the tertiary rocks. The nummulitic deposits are not found in the middle of the synclinal basins, in sequence with the upper secondary deposits: they seem, on the contrary, to be as far as possible out of connexion with the general sedimentary series, occupying, as they do, a long trough in the Indus valley, in or adjoining the metamorphic rocks of the Ladák gneissic axis. This feature is so very marked, as laid down for 200 miles, between Háule and Kargil, by Dr. Stoliczka (who identified nummulitic rocks in no other position), and the significance of the tertiary rocks in the history of the mountains is so great, that special interest attaches to observations on this formation.

Gneiss of two ages.—It was fully shewn by Dr. Stoliczka that the metamorphic rocks of the Himalayas are extensively formed of converted palæozoic formations, in continuous relation with unaltered rocks of the same period. The whole of the gneissic axis in Ladák is considered to be so constituted. Elsewhere, unaltered lower palæozoic strata of great thickness are found in abrupt contact, at their base, with gneissic rocks. Two sections of this kind are recorded; both are in the main

Himalayan range, and on the confines of the area described as the Lower Himalayas. The descriptions of the contact are not very precise, but there can be little doubt that the slates were deposited upon a floor of gneiss. In Hundes General Strachey describes and figures some 2,000 feet of infra-silurian azoic slates overlying the crystalline schists in immediate, parallel succession, with a band of coarse conglomerate at or near the junction.[1] The granite of the adjoining axis of intrusion penetrates these slates for a short distance, without producing any great alteration. In the corresponding section described by Dr. Stoliczka on the Bhábeh pass, at the south-east corner of the Zánskár basin in Spiti, a similar relation was observed. The actual contact was concealed by snow; but the lower rocks maintained their gneissic character to the top, and the nearest outcrops to them were of grey slates and sandstones, the lowest beds of a long series of lower silurian strata, quite unaffected by crystalline metamorphism. The latter are probably the same as the infra-silurian beds of Hundes. The dip is somewhat higher in the gneiss than in the slates, suggesting some unconformity or faulting at the contact; but this is not certain, as the observations were some distance apart. Transitional metamorphism is, however, out of the question.

The central gneiss.—We thus have an important fact established, that of an older and a newer gneiss, the difference in age between them being necessarily very great; so that the distinction of the two is a point of much importance in the geology of the mountain region. It was, no doubt, partly to mark this distinction of age, that Dr. Stoliczka gave the name *central* to the gneiss of the main Himalayan axis. The term is certainly ambiguous, and we have already (p. 597) pointed out one important correction in the extension given to it by Dr. Stoliczka; but it may as well be retained, not in the sense of *axial*, but simply as denoting the fundamental formation of the Himalayan rock-series.

Mineral character.—It is unfortunate that so important a distinction depends for detection upon such uncertain criterions as the mineral constitution of metamorphic rocks, and characters so generally obscured as those of contact-relations. The central gneiss is normally composed of white quartz with white felspar (orthoclase or albite), which often forms large crystals, in the more massive varieties of the rock; and the basic mineral is mica (biotite or muscovite), often abundant in the more schistose varieties. The rock of the Ladák gneissic axis is, on the contrary, chiefly syenitic. This cannot, however, be taken as a sure criterion; for elsewhere the silurian slates are found converted into ordinary gneiss.

[1] Q. J. G. S., VII, p. 302.

Stratigraphical relation.—The stratigraphical relation is also of most uncertain application. It is evident that if a later metamorphism had converted the slates of the Niti or the Bhábeh sections, where the two series are in parallel succession, into gneissic schists, the great distinction betrayed by the actual relations (perhaps the greatest in the whole sequence of formations) would have been altogether obscured, and the whole would appear as one continuous metamorphic series. This is precisely the difficulty encountered in attempting to follow out the central gneiss to the north-west, in immediate continuation of the main Himalayan axis; and the same impediment would of course render it still more difficult to detect the older gneiss in a detached area, surrounded by a later gneiss, as in the Ladák axis, or elsewhere. Even along the south boundary of the central gneiss, in the Lower Himalayan area, where there is great unconformity between the gneiss and the slate series (as that unconformity does not involve oblique discordance of stratification), it has been a matter of great difficulty to detect the distribution of the two series, and almost impossible to delineate their separation with any accuracy; the originally highly contrasting conditions of the rocks having been so disguised by the subsequent metamorphism of the newer series, especially near the contact of the two.

Relations defined only in the middle Himalayas.—The very striking contrast of the relations between the central gneiss and the slate series, on the north and on the south, would be a remarkable fact, if it should be confirmed by more extended observations that, as is believed, the two slate series are identical. On the north there is quasi-conformity of superposition, while on the south, as we have seen (p. 601), the newer series overlaps and abuts against denuded masses of the older.[1] From this latter relation it was shewn that the central gneiss must have formed a primitive ridge, to some extent corresponding in position with the Lower Himalayan area. In spite of the contrasting stratigraphy, the northern sections confirm this impression, in that they shew, what was not demonstrable on the south, however apparently probable, that the gneiss underwent its metamorphism in pre-silurian times; and further, it can so far be stated that the evidence for this condition is limited to the confines of the Lower Himalayan area, or a middle Himalayan position with reference to the whole mountain range; everywhere else, in Zánskár, Pángi, and the Pir Panjál, the slates become schistose, and are more or less transitional with the underlying gneiss; or, in other words, the slates along the

[1] It should be recollected that the nearest outcrops exhibiting this contrast are 30 apart.

northern border of the Lower Himalayan area have not been subjected to the metamorphic action which they have undergone more or less generally in other parts of the mountains: a fact that would be most naturally explained by these slates never having been so depressed, or subjected to so great crushing, whereby the silurian rocks of the Ladák axis and elsewhere were converted into gneiss. Thus, from the side of the Central Himalayas, in the north, we find confirmation of the evidence brought forward from the tertiary rocks on the south, and from the rock-structure of the Lower Himalayas themselves, that this latter area holds a peculiar, and more or less neutral or independent, position in the Himalayan system.

Although not fully identified out of the Lower Himalayan area, nothing is more likely than that the central gneiss should occur elsewhere; and it has been recognised with much probability in several positions in the divided north-western ranges on the continuation of the main range. Dr. Stoliczka thought he recognised the same rock well to the north of the main range near Changrizing, east of the Pára river, at the base of the great Purgial mountain, which separates the basin of Zánskár from that of Hundes.

The granitic axis.—There is no more unique or debatable feature in the Himalayas than the granitic axis, so persistent along the main range. To the east in Sikkim, and in the north-west, from the frontier of Nepál to Kulu, wherever examined, coarse white granite has been found in profusion along the line of peaks, near the present edge of the sedimentary basin of Tibet. It occurs in veins and dykes of every size, sometimes forming the massive core, up to the summit, of the highest mountains.

The width of the band of intrusion seldom exceeds 25 miles, and is generally much less. The rock dies out completely to the west, being only very feebly represented at the Báralácha pass, the most distant point at which it has been observed in the ranges beyond the Lower Himalayan area, with which again this peculiar feature is nearly coterminous.

This granite is pre-eminently the axial rock of the main Himalayan range, as a geographical feature; and this fact, perhaps, was partly the reason why the name "central" was given to the gneiss in which it occurs, with the implied suggestion that this gneiss had been upraised with the granite; for the contiguous gneiss to the south was regarded by Dr. Stoliczka as distinct. This view has, however, been shewn to be untenable (p. 597); and it is very open to question whether, in any proper geological sense, this line of eruptive rock can be considered an axis

(*locus*) of elevation. The supposition would be incompatible with the inferences already drawn from the circumstances of the sedimentary rocks on both sides of the central gneiss of the Lower Himalayas, shewing absolutely (if correct) that the slate series had never been continuous across that area. It is more likely that the granite marks a marginal line of irruption, with reference to the main area of deposition from which the Central Asian plateau was to arise. From general considerations on the drainage system it will be suggested that the crest of the Himalayan elevation lay far to the north of the present main range. General Strachey describes the granite as penetrating the slates, and the same authority is quoted by Dr. Stoliczka[1] for its reaching the secondary formations. It can scarcely be of later date.

Terminal extensions of the central gneiss.—The distinction of middle and terminal characters is nowhere more marked than in the main Himalayan range, which may, in fact, as a geological feature, be said to end with the Lower Himalayan area. Beyond this, to the north-west, there are three independent ranges with gneissic axes, all connected with the central gneiss, and each having some pretension to be considered the continuation of the main range of the middle Himalayas.

The Zanskar gneissic range.—Immediately north of the Sutlej, and west of the Bhábeh section described by Dr. Stoliczka, there is a great nucleus, or stratigraphical node, of high mountains, ranging to 21,772 feet in elevation, in Waziri Rupi, a district of Kulu. The mass lies for the most part to the north of the prolongation of the main chain. In fact, from the Sutlej, at about the Bhábeh pass, there is a rather abrupt change of about 25° in the strike of the Central Himalayan axes, on opposite sides of the Purgial transverse ridge. The strike of the Hundes basin, and of the main gneissic range south of it, is about west-35°-north; while that of the Zánskár basin, and of the gneissic range outside it, is west-60°-north. The Zoji-La from Kashmir, and the Báralácha from Láhul, are the best known passes in this latter range; and the name of the latter pass has been sometimes applied to the range itself; but it is better to use a term of greater original extension, such as that of the central district of Zánskár. Several of the peaks range above 20,000 feet in elevation.

For many reasons, geological as well as geographical, the Zánskár range has a right to be considered the principal continuation of the Himalayan chain. In its centre, south-west of Zánskár, for a width of nearly 50 miles, it is formed entirely of gneiss; but this rock rapidly contracts to the north-west, and dies out altogether before reaching the Zoji-La, where the sedimentary formations roll over from Tibet into

[1] Mem. G. S. I., Vol. V, p. 12.

Kashmir, and form the mountains on the north side of the valley, at a considerably lower elevation than the gneiss-formed peaks of the range in Zánskár. Here, then, we have a complete terminal occultation of the gneissic axis, in the principal north-western representative of the Himalayan range.[1] The width of the gneiss contracts also very much on the south-east: Dr. Stoliczka observed a band, only 6 miles wide, of what he took to be the central gneiss, low on the south side of the Báralácha pass. It will, however, be shewn that the gneiss of Zánskár is, to some extent at least, a newer rock, formed of converted palæozoic strata.

The Pir Panjal gneissic chain.—If the question of representative ranges were to be settled by the continuous line of greatest elevation, the Zánskár range would have to cede its claim; for the col or gap (the Kunzum pass, on slates, at 14,931 feet), connecting it with the gneissic mass of Rupi, is lower than the Rotáng pass (on gneiss, at 15,206 feet), dividing the mountains of Rupi from those of Bara-Bhagál and Barmaur, which range to above 20,000 feet. It is still unsettled whether the slates of the Kunzum pass are not continuous with those immediately north of the Hamta and Rotáng passes, so as to cut off the gneissic mass of Zánskár. Dr. Stoliczka notes also "the characteristic of albite granite in the gneiss of the Hamta pass."

This Rotáng ridge at the head of the Kulu, or upper Biás, valley is certainly the most direct continuation of the mountains of Rupi; and on this line we find the greatest prolongation of gneissic rock, through Barmaur, Chamba, Badrawáh, and Kistwár, to the Pir Panjál, bounding the Kashmir valley on the south-west. The crest of this chain is more irregular than those we have hitherto spoken of, and this irregularity has always caused a difficulty in finding a name for it. It is perhaps best to extend the well-known name of Pir Panjál to the whole of it. Even in the Pir Panjál proper, the ridge is very irregular, and the gneiss is not continuous throughout; but in this broken fashion the rock continues across the Jhelum to beyond Kashmir, where its mode of termination in the Kishenganga valley is not known; but it probably does terminate there.

[1] To the great disappointment of geologists, all mention of the rocks seems to have been carefully excluded by that accomplished observer Mr. Drew from his most interesting work on the Jummoo and Kashmir Territories. One of the very few remarks that have escaped him records (p. 378) the occurrence of mountains of grey granite on each side of Stakpi La defile, and something less than 2,000 feet above it, between the Burzil branch of the Kishenganga valley and the head waters of the Shingo river. The locality would be nearly on the prolongation of the Zánskár axis, but it probably belongs to a local focus of disturbance in Little Tibet.

In this chain also, according to the few observations on record, the relation of the gneiss to the slates is not of so decided a character as in the Lower Himalayan region. There is generally more or less of transition, and it is difficult to make sure whether we have to deal with the older or the newer gneiss. The abrupt manner in which the semi-detached gneissic masses are intercepted by schists and slates is especially hard to reconcile with other structural features of the sections, as will be indicated in connection with the slate series; but the arrangement of these quasi-continuous masses, independent of an approximately axial position—and there are some, such as the Kund Kaplás mountain in Badrawáh, which cannot pretend to belong to the Pir Panjál chain—is suggestive that the relations of the slates to the gneiss here may be the result, in a minor degree, of an original relation like that described on the south side of the Lower Himalayas in the Simla region, where the slate series was shewn to have been deposited amongst steeply eroded masses of the central gneiss (p. 605).

There is, however, one remarkable observation by Mr. Lydekker[1] in the slates of the Pángi basin, in the upper Chináb valley, separating the Zánskár range from the almost equally high mountains of the Pir Panjál in Chamba, shewing that at the time of the deposition of these slates the central gneiss was undergoing extensive erosion at no great distance. In the midst of the black slates, throughout a thickness of some 2,000 feet, large blocks of granitoid gneiss, either angular or water-worn, are scattered in great numbers. They are well seen about the village of Salgraun (25 miles above Kilár). Some were measured as much as three and a half feet in diameter; and being embedded in fine slate, it seems necessary to suppose that they were in some manner erratics, *i. e.*, transported by some form of flotation or suspension, distinct from the ordinary denuding agencies of water and gravitation only.

The Dhauladhar gneissic range.—There is one other gneissic ridge that might be considered the legitimate representative of the Himalayan axis proper, as being most nearly on its prolongation, in its normal direction. The Dhauladhár is remarkably well defined as a geological axis, although at the very edge of the mountain area, overhanging the tertiary zone in the Kángra valley, and separating this zone from the basin of slates in the upper Rávi valley, which, again, divides the Dhauladhár from the Pir Panjál range in Barmaur. The Kulu valley, which is the upper valley of the Biás, running due south from the Rotáng pass, completely cuts off the Dhauladhár from direct continuity with the mountains of Rupi; but the connexion is maintained at a very high level, from

[1] Rec. G. S. I., XI, p. 54.

the Rotáng pass through the mountains of Bara Baghál, separating the head waters of the Biás and the Rávi. There seems little doubt that the gneiss of the Dhauladhár is to some extent, if not altogether, the central gneiss; but it ends completely and abruptly at Dalhousie, where the Rávi turns round it, at right angles to its course within the mountains. This is a conspicuous instance of the feature already mentioned as so difficult of explanation, and upon which some detailed observations are very much needed.

The newer gneiss.—In preceding paragraphs frequent mention has been made of the newer gneiss; of its special (syenitic) mineral characters where the lower palæozoic formations have been metamorphosed on a large scale, as in the Ladák axis, and of its more ordinary condition where mineralised in connexion with the old gneiss in its extensions to the north-west. Any further mention of the newer gneiss will be made in tracing the general distribution of the palæozoic rocks themselves.

The chief sedimentary basins.—The skeleton of the mountain structure delineated in the foregoing paragraphs, shewing the position and nature of the gneissic axes, will help to elucidate the distribution of the fossiliferous formations, and will suggest at once the convenience of dividing the description according to the great areas, more or less separated, in which these rocks are now found: the two central basins of Zánskár and Hundes or Ngári-Khorsum; the northern basin of the Kárákoram; and the southern area of Kashmir and Pángi.

In speaking of these areas as basins of sedimentary rocks, we do not, of course, mean basins of deposition, but simply stratigraphical basins. They are certainly now basins of disturbance, great synclinal troughs; but it is a leading point of inquiry,—to what extent in any of the successive formations, if at all, the areas of deposition corresponded with these areas of present relative depression of the rocks? The available observations are much too cursory and scattered to support a definite opinion upon this point; but if we might extend to this ground the inference arrived at in the other Himalayan regions, that the palæozoic rocks had undergone no contortion prior to the eocene period, we could not look for much agreement in detail between the actual results of disturbance and the original distribution of the pre-tertiary sedimentary series. Whatever may have been the circumstances which resulted in the striking discrepancy between the rock-series of the Central and the Southern Himalayan areas, whereby all the secondary formations, or at least all the middle and upper groups of that period, were excluded or removed from the southern area, it might seem fair to suppose that the great contortions and dislocations affecting the southern region were more or less of syn-

chronous origin with the similar and connected features in the adjoining area; and, therefore, that the great axes of flexure which now define the rock-basins of Tibet are of post-eocene origin. The very marked approximate conformity exhibited throughout the whole sedimentary series up to the cretaceous deposits, as represented in the sections of the Zánskár basin figured by Stoliczka, and the certainty that at the close of the cretaceous period some of the highest summits of Tibet were at the sea-level, would seem to support the view, that in this region also the beginning of special Himalayan disturbance was posterior to the eocene period.

We must, however, beware of inferential assumptions, however plausible. Enough has been seen in the Sub-Himalayan ground to warn us against placing much reliance upon conformity or unconformity, within very close proximity, in these mountain sections; and the most marked stratigraphical feature of Tibet—the complete severance of continuity between the eocene and the cretaceous deposits—implies great changes in the intervening time, and has a direct bearing upon the point at issue; only we have no observations as to the full or special meaning of this feature. Eocene deposits of great thickness occupy a long trough in the silurian gneiss of the Ladák axis. No one has suggested that they were let down into this position by faulting; so there must have been immense pre-tertiary denudation, with a corresponding rise of the Himalayan area. It is just possible that the original relation in Tibet may have been the same as that already shewn for the nummulitic beds in the Simla region, where they were laid down on deeply eroded, but as yet uncontorted, palæozoic rocks. The fact that the palæozoics of Tibet had been previously converted into gneiss would not absolutely preclude this condition (for the central gneiss is the least disturbed of all the Himalayan formations), although certainly rendering it far from probable.

The settlement of this question—the original relation of the nummulitic formation in Tibet—is a point of extreme interest in Himalayan geology. If it should be proved that that relation was the same as in the Lower Himalayan area—that the immense pre-tertiary denudation of the Central Himalayan region had taken place previous to any great contortion of the strata there—we should have something like a demonstration of the DeBeaumont theory of mountain formation: that the first stage in the process is of the nature of a great warp or deformation of the earth's crust, the collapse (*écrasement*) of which state of tension results in the flexures and dislocations which characterise every region of true mountains.[1]

[1] DeBeaumont's theory of mountain formation is so commonly identified with his final speculations upon the question of direction, that it is necessary to point out that his preliminary discussion of the conditions is independent of that elaborate development.

The formations of the Zanskar area.—Dr. Stoliczka's first work in Tibet (the only exploration of which he published any detailed observations[2]) was confined to the south-east end of the Zánskár area, in the Spiti and Pára valleys, and through Rupshu (or Rukshu) to the Indus. On his second trip he made several traverses of a much larger area, up to the north-west termination of the basin at Kargil; but only brief route-notes were published.[3] The length of the area is 200 miles, with a maximum width of 50 miles in Zánskár. The following detailed characters of the rocks, and for the most part the fossils also, are taken from the former ground; they will serve for general comparison. The names also are taken from localities in Spiti and Rupshu, where the several formations are well exposed. No groups were added from the examination of the larger area to the north-west

FOSSILIFEROUS SERIES OF THE ZANSKAR AREA.

MESOZOIC:

(*n*) CHIKKIM SHALES (*Cretaceous*).—Dark grey, marly, earthy shales. Thickness, 200 feet. No fossils; considered to be closely related to the limestone.

(*m*) CHI[illegible] *'Cretaceous*).—White, or grey on fresh fracture: when [illegible] a strong bituminous odour when struck. Thick-[illegible]

[illegible] *Rot*[illegible]	*Textilaria*, 2 sp. *Haplophragmium*, sp. *Cristellaria*, sp.

(*l*) GIEUMAL SANDSTONE (*Upper jurassic*).—Light yellowish, silicious; darker and calcareous, fossiliferous; sometimes a loose grit, and even coarsely conglomeratic. Thickness, 600 feet; conformable to and interstratified with *k*.

Opis, sp.	*Mytilus mytiloidca.*
Anatina spitiensis.	*Avicula echinata.*
A. sp. nov.	*Gyphæa*, sp.
Pecten bifrons.	*Ostrea*, sp., near *O. gregaria.*
Amusium demissum.	*O.* sp., near *O. sowerbii.*
Lima, sp.	

[1] Mem. G. S. I., III, Pt. 2, p. 174; and Q. J. G. S., XXIV, p. 48.

[2] Mem. G. S. I., V, 1865, pp. 1–154.

[3] Mem. G. S. I., V, 1866, pp. 337–354.

(*k*) SPITI SHALES (*Upper jurassic*).—Black, crumbling shale, full of calcareous concretions, each generally containing a fossil. Thickness, 300 to 500 feet; in Spiti they rest conformably on *g*, the lower Tagling limestone.

Belemnites canaliculatus.	*Astarte unilateralis.*
B. clavatus.	*A. major.*
Anisoceras gerardianum.	*A. spitiensis.*
Ammonites acucinctus.	*A. hiemalis.*
A. strigilis.	*Trigonia costata.*
A. macrocephalus.[1]	*Cyprina trigonalis.*
A. octagonus.	*Nucula cuneiformis.*
A. hyphasis.	*N.* sp.
A. parkinsoni.	*Arca* (*Macrodon*) *egertonianum,* Pl. XII, fig. 14.
A. theodorii.	*Inoceramus hookeri.*
A. sabineanus.	*Lima*, sp., near *L. rigida.*
A. spitiensis.	*Aucella blanfordiana.*
A. curvicosta.	*A. leguminosa*, Pl. XII, fig. 15.
A. braikenridgii.	*Amusium* (conf. *Pecten stolidus*).
A. nivalis.	*Pecten lens.*
A. liparus.	*Ostrea*, sp.
A. triplicatus.	*Rhynconella varians.*
A. biplex.	*Terebratula* sp.
A. alatus.	*Salenia ?* sp.
Pleurotomaria, 2 sp.	
Homomya tibetica.	

(*i*) SHALY SLATES (*Jurassic*).—Brown or black; full of broken shells. Thickness, 50 feet; very local; probably belong to *k*.

Belemnites, sp.	*Posidonomya ornata.*

(*h*) UPPER TAGLING (*Lias*).—Dark, earthy, bituminous; only described north of Spiti. Thickness, nearly 1,000 feet; difficult to distinguish from *g*.

Belemnites, sp.	*Trochus epulus.*
Ammonites (conf. *macrocephalus*).	*T. attenuatus.*
Nerinea (conf. *N. goodhalii*).	*Chemnitzia undulata.*
Acteonina (conf. *A. cincta*).	*Neritopsis* (conf. *N. elegantissima*).
Eucyclus (*Amberleya*), sp.	*Modiola*, sp. (resembling *Mytilus subreniformis*).
Trochus latilabrus.	*Terebratula sinemuriensis.*

g) TAGLING LIMESTONE (*Lower Lias or Rhætic*).—Dark grey, brown or black, sandy or earthy, often oolitic and bituminous, sometimes a shell-limestone; weathers light brown, rusty. Thickness, more than 1,000 feet; locally unconformable on *e*.

Belemnites budhaicus.	*Nerinea*, sp. (near *N. goodhalii*).
B. bisulcatus.	*Chemnitzia* (conf. *C. coarctata*).
B. tibeticus.	*C.*, sp. (near *C. phidias*).
Ammonites (conf. *A. germanii*).	*Natica* (conf. *N. pelops*).
A., sp. (conf. *A. macrocephalus*).	*Nerita*, sp., nov.
	Dentalium, sp. (near *D. giganteum*).

[1] According to Dr. Waagen, Palæontologia Indica, Ser. IX, 3, p. 237, foot-note, this and several other species are not identical with the European fossil forms to which they were referred by Dr. Stoliczka.

Arca (*Macrodon*), sp. (apparently *A. lycetti*).
Gervillia, sp. (near *G. olifex*).
Avicula inæquivalvis.
A. punctata.
Lima densicostata.
Pecten (conf. *P. palosus*).
P. moniliger.
P. sabal.
P. bifrons.
P. valoniensis.
Amusium, sp.
Ostrea (conf. *O. acuminata*).
O. (conf. *O. anomala*).
Rhynconella obtusifrons.
R. pedata.
R. fissicostata.
R. austriaca.
R. variabilis.
R. ringens.
Terebratula gregaria.
T. pyriformis.
T. punctata.
T. (*Waldheimia*) *schafhæutli.*

(*f*) PÁRA LIMESTONE (*Rhætic or Upper Trias*).—Black, dolomitic, strongly bituminous, often earthy. Thickness, 700 feet; only found on north side of Spiti.

Dicerocardium himalayense, Pl. II, fig 7.
Megalodon triqueter, Pl. II, fig. 8.

(*e*) LILÁNG SERIES[1] (*Upper or Middle Trias*).—Dark limestone, calcareous slates and shales; limestone compact or finely oolitic; lower beds quasi-concretionary. Thickness, 1,000 to 2,000 feet; locally unconformable on *d*.

Orthoceras, sp.
O. salinarium.
O. latiseptum.
O. dubium.
Nautilus spitiensis.
Clydonites oldhamianus, Pl. II, fig. 4.
C. hauerinus.
Ammonites floridus, Pl. II, fig. 1.
A. jollyanus.
A. khanikofi.
A. gaytani.
A. diffissus, Pl. II, fig. 3.
A. ausseanus.
A. gerardi.
A. medleyanus.
A. studeri.
A. thuillieri, Pl. II, fig. 2.
A. malletianus.
A. batteni.
Pleurotomaria (conf. *P. buchi*).
P. sterilis.
Discohelix, sp.
Myoconcha lombardica.
Lima (conf. *L. ramsaueri*).
L., sp., nov.
Monotis salinaria, Pl. II, fig. 6.
Halobia lommeli, Pl. II, fig. 5.
Waldheimia stoppanii.
Athyris strohmeyeri.
A. deslongchampsi.
Rhynconella mutabilis.
R. theobaldiana.
R. salteriana.
R. retrocita var. *augusta.*
Spirifer, sp. n.
S. (*Spiriferina*) (conf. *S. fragilis*).
S. (*Spiriferina*) *stracheyi*, Pl. II, fig. 9.
S. (*Spiriferina*) *lilangensis.*
S. spitiensis.
Encrinus cassianus.

[1] The following triassic and rhætic fossils are figured on Plate II:—

Fig. 1. *Ammonites floridus* ½.
" 2. *A.* (*Ceratites*) *thuillieri* ½.
" 3. *A. diffisus.*
" 4. *Clydonites oldhamianus.*
" 5. *Halobia lommeli.*
Fig. 6. *Monotis salinaria* ½.
" 7. *Dicerocardium himalayense* ½.
" 8. *Megalodon triqueter* ½.
" 9. *Spirifer stracheyi.*

PALÆOZOIC:

(*d*) KULING SERIES (*Carboniferous*).—Pale quartzites (fossiliferous) generally at base, but alternating with brown shales; the latter are often carbonaceous and calcareous, passing into dark limestone. Thickness, 100 to 400 feet; junction with (*e*) conformable, obscure.

Orthoceras, sp.	*P. semireticulatus*, Pl. I, fig. 8.
Aviculopecten, sp.	*P. longispinus*.
Cardiomorpha, sp.	*Spirifer moosakhailensis*, Pl. I, fig. 2.
Avicula, sp.	*S. keilhavii*, Pl. I, fig. 1.
Productus purdoni, Pl. I, fig. 10.	*S. tibeticus*.
	S. altivagus.

(*e*) MUTH SERIES (*Upper Silurian*)—

White quartzite, often speckled; no fossils. Thickness, 200 to 300 feet.

2. Pale sandy and silicious limestone, purer beds dark; weathering brown; fossiliferous. Thickness, 300 to 400 feet.
1. Purple sandstone, slaty partings; conglomeratic; no fossils. Thickness, 500 to 600 feet; conformable to *b*, slightly alternating.

Tentaculites, sp.	*Orthis*, sp. (near *O. tibetica*).
Strophomena, sp.	*O.*, sp. (conf. *O. resupinata*).
Orthis, sp. (near *O. thakil*, var. *striatocostata*, and var. *convexa*).	Crinoid stems.
Orthis, sp. (near *O. compta*).	*Cyathophyllum*, 2 sp.
	Syringopora, sp.

(*b*) BHÁBEH SERIES (*Lower Silurian*)—

3. Greenish and bluish sandstones sometimes micaceous, often laminated; also thickly bedded, occasional slaty and calcareous beds, fossiliferous. Thickness not stated, but represented in the section as equal to 2 or 1.
2. Grey, white and pinkish, speckled sandstone or quartzite, with occasional calcareous beds, dolomitic and cavernous (Rauchwake), fossiliferous. Thickness not stated; figured as much as No. 1.
1. Bluish and greenish grey slates (some micaceous) and sandstones; no fossils. Thickness, 3,000 feet.

Orthis, sp.?	*Chætetes yak*.

Palæozoic series.—A large part of Stoliczka's Memoir is given to the description and discussion of the fossils, a complete list of which has been given above; besides this there is not much matter for discussion, and it would be too tedious without a full-scale map to trace the formations severally wherever they have been observed. It will be more suitable here to take them up in series, and to indicate the conditions they exhibit at different points of the area. This sketch possesses the advantage, so rarely experienced in Indian formations, that the stratigraphical identifications were made upon the basis of palæontological evidence. The palæozoic series, as given in the above list, is, of course, only illustrative, not in any sense a standard; even here, in several of the groups,

much variation is noticed. The observations were taken at the south-eastern extremity, where the Zánskár basin approaches nearest to the Lower Himalayan area, and where the strata exhibit a minimum of alteration. It is only in this portion of the area, within the Spiti basin, which drains into the Sutlej, and has undergone the greatest erosion, that the upper palæozoic rocks are freely exposed, away from the edge of the basin. In Spiti the Kuling series is very frequently found at the bottom of the deepest valleys, underlying the secondary formations of the adjacent mountains. In the more elevated ground of Zánskár it has been noticed only in a few localities in this position, as in the Tzárap valley. There is no mention of the silurian rocks being exposed, except along the marginal outcrops.

South-west boundary.—To the north-west of Spiti the palæozoic series is still recognisable at the Báralácha pass. The rocks immediately above the central gneiss are like those of the Bhábeh section; and fossils were found at a low horizon in the silurians. The next section is on the Zánskár river, near Padam, where the boundary between the two series is not fixed, within broad limits; and from this to the westward, along the flank of the Zánskár ridge to Suru (Sooroo), near the north-west end of the Zánskár basin, the metamorphism increases, and the whole palæozoic series becomes gradually disguised. On the Suru section the metamorphics of the Zánskár range extend northwards to Sangra, near Kartse (Kurtse), where they are largely hornblendic, and supposed to be upper silurian. The chloritic quartzites north of this are considered to be carboniferous, and they are in contact with the syenitic rocks of Kargil, against which the sedimentary basin terminates on the north-west.

South-east boundary.—Proceeding north-eastwards from the Bhábeh pass, we follow the south-east end of the Zánskár basin, as stopped out against the central gneiss of Purgial. The details of this feature have not been observed, but, as seen in the section of the Spiti river, only 25 miles from Muth, some important changes are recorded. Fossils were found far down in the series, near Kuri and Shálkar. The gneiss is overlaid by dark, thin-bedded slates and sandstones, but apparently not immediately; for the chief contrast between this and the Bhábeh section is stated to be that the lower strata on the Spiti are more altered, in a few places truly metamorphic, and that the higher beds are more slaty. But the most peculiar difference is the appearance of interbedded greenstone throughout the whole series, from the gneiss up to the carboniferous rocks near Po (on the Spiti river). The thickness of the deposits seems to be greater here, especially of the carboniferous series, if all the brown shales at the top of the section belong to this formation.

The disturbance is not excessive; it is locally described as if the schists had been upheaved in the form of a dome.

The Rupshu metamorphics.—The next section is 40 miles to the north, in the upper valley of the Pára river, where the conditions of the north-east boundary are fully established. The first effects of metamorphism are noticed in the triassic rocks; but the greenish quartzites and slates beneath them are still recognisable as of the Kuling series, and have yielded carboniferous fossils. Beneath the quartzites and slates come chloritic and mica-schists, doubtless representative, if the observations be correct, of the silurian rocks, but differing entirely from them in facies. The south-westerly dip continues remarkably constant for 24 miles across a vast thickness of these metamorphic strata, a third of which would amply represent the known thickness of the lower palæozoic series; so that, unless there are undetected repetitions, there must be either great expansion of these formations, or we have here also an unknown thickness of the old gneiss. This would seem by no means improbable; for below some 10,000 feet of the mica-schists, at about the middle of the Moríri lake, there is a strong band of granitoid rock, not unlike the central gneiss. It is underlaid by a great series of thin quartzose schists, locally gneissose, below which, at the Kiágar lake, is another mass of gneiss, characterised by large imperfect crystals of felspar and much tourmaline. This gneiss is thin-bedded, and passes down again into quartzose schists. At last, within six miles of the Indus, there is a reverse (north-east) dip in these beds, and so they abut against (are traversed by) a great mass of basic igneous rock, forming a line of irruption along the Indus.

A passing reflection may be recorded on the absence, in the infra-carboniferous rocks of Rupshú, of bedded greenstone, so abundant throughout the silurians of the Spiti valley. The fact would be enough to awaken doubt whether any of these metamorphics can be converted silurians; save that the total absence of those same rocks in the Bhábeh section rather suggests that they are not truly contemporaneous in the Spiti ground.

The Rupshu metamorphics continue to the north-west, with a constantly diminishing width, the massive gneiss being still in force at Gya (36 miles south-south-east of Leh), where it is described as having a large proportion of white quartz, but the mica is occasionally replaced by diallage. This is close to the axis of eruptive rock.

North boundary with tertiary rocks.—Not far to the west the Rupshu metamorphics must die out altogether; for at the Zalung Karpo pass, 15 miles west of Gya, carbonaceous slates and limestones underlie the Liláng (triassic) limestone, and are the only rocks seen from this

all down the Marcha valley to Skiu, near the Zánskár river, where carbonaceous limestone, full of crinoid stems, and presumably carboniferous, is in close proximity to the nummulitics. Silurian rocks were not distinguished in this section, but Stoliczka considers that they are probably present. The eruptive rock is not noticed in the section at Skiu. The next section is 30 miles west of the Zánskár river, on the road from Drás to Leh. Here the slates, green and red shales and sandstones, between the serpentine of the Indus and Lámayúru, are recognised as of the Bhábeh series. They are contorted, with a prevailing south-west high dip, and are overlaid by a few hundred feet of carbonaceous shales, which are spoken of as of the Muth series, and also as carboniferous.[1] The rocks are spoken of as highly metamorphic-looking, and at the same time as not easily distinguished locally from the adjoining tertiary rocks. Farther on, west of Kharbu, the tertiary rocks, both sedimentary or igneous, encroach still more; and about Shargol they are in obscure contact with the triassic limestone. The next mention of the palæozoic series is at 16 miles to the west, where we have already seen them, much altered, in contact with the syenite of Kargil.

Thus it appears that for about half its length, on the north, the Zánskár basin of palæozoic and secondary rocks is now bounded by tertiary formations. On the north-west these contiguous, but distinct, basins end together against the syenitic mass of Kargil; but to the south-east the tertiary rocks pass continuously into the broad central area of metamorphic rocks, those of Rupshu on the south-west, and those of the Ladák range on the north-east. The latter will be noticed in connexion with the Kárákoram area, where they are described in sequence with the fossiliferous rocks of that basin.

The secondary series.—The series of secondary formations in the Zánskár area, recorded in the list at p. 635 amounts altogether to a thickness of 8,000 to 9,000 feet. From the structural condition of the area, shewing that it is proximately at least a basin of disturbance, the general distribution of the formations may be surmised; and we have already traced a continuous outcrop of the palæozoic rocks round the edge of the basin, except on the north, where the structural symmetry is broken by the contact of an independent and much later basin of tertiary rocks. As there is general conformity throughout the entire sequence of formations, each is principally exposed along the external outcrop of its area, and then along the sides of the deeply eroded river gorges traversing the basin, where all the strata are variously affected

[1] These observations are taken from Stoliczka's notes, in the Scientific Results of the Second Yárkand Mission: Geology, pp. 13, 14: Calcutta, 1878.

by minor undulations and contortions. The great limestones of the Liláng and Tagling groups are the most prominent rocks of the area; while the later formations—upper jurassic and cretaceous—are reduced to comparatively small patches in the centre of the basin, in the hollows of local synclinals or as remnants on the tops of ridges.

On the much more obscure question of the original distribution of these formations, there is very little to be said. It is important to record the few remarks on this point made by the observer himself, from whom these descriptions are taken. In his reflections on his second year's work Dr. Stoliczka remarks (*l. c.*, p. 352): "Referring to the section near Muth, as far as I can see now, I believe that the carboniferous deposits here seem to close a grand geological epoch, and that in the main their deposits filled only the interior of a large basin, which gradually and partially became dry land. The carboniferous rocks now appear sparingly dispersed in consequence of undulating contortions of the entire ground. Towards the west, especially in Kashmir and Little Tibet, the carboniferous rocks are, however, much more developed." On the same page it is written, that "after the close of the triassic group in the North-West Himalayas, great disturbances must have taken place; large tracts of the country were raised, and never more covered by the sea, until partially in comparatively recent periods (eocene), while in other places the regular succession of deposits took place. One of these was evidently the large northern jurassic basin of the Himalayas." Again, a little further (*l. c.*, p. 353): "The jurassic basin, which is so well developed in Spiti, and extends to North Kumaun, continues to retain the same north-western direction, with all the characteristic rock-formations, until it becomes interrupted by the great granitic and syenitic mass of Little Tibet. A partial interruption seems to have taken place after the close of the rhætic deposits; but whether the jurassic basin has been actually and totally interrupted here (that is, south of the Indus), or whether it has been only compelled to continue with its course towards the north or north-west in Gilgit and beyond the Mustágh range, subsequent inquiries must prove."

The particular observations upon which these impressions were based are not indicated; and it must be said that from an independent study of the recorded observations, such inferences could not be made, or even that a different interpretation is suggested. No facts are quoted shewing the great disturbance of the Liláng series independently of the later formations, preparatory to the formation of the jurassic basin. The lower jurassic group, the Tagling limestone, appears in full force, forming the highest summits close to the edge of the basin, both on the north and

south; and the original limitation of the jurassic rocks anywhere near this seems to be purely conjectural. The only instances given, in the Pára and upper Tagling limestones, of interpolation and thickening of strata have no reference to the actual basin; they begin to the north of its centre, and expand towards its present north margin. The only appearance of an original basin, corresponding with the actual one, is in the upper secondary deposits—the Spiti and Chikkim groups; and even for these the case is not very evident. The best case quoted is that at Muth, where the carboniferous (Kuling) group seems to be regularly overlapped by the Liláng beds; but this, like the two cases just mentioned, only points to a southern limitation of the Himalayan deposits. The greatest difficulty in the way of the latter supposition, as a general feature, is the great thickness of the silurians in the Bhábeh section; the only relief to it being the preponderance of sandstone in that position, contrasting with finer deposits elsewhere. On the whole, it is evident that the date of formation of the Zánskár basin is still an open question, within very wide limits.

The tertiary series.—It is in connection with the Zánskár area and Dr. Stoliczka's work that we have to notice the tertiary rocks of the Central Himalayas. Here, as in the Sub-Himalayan zone, their features and relations are of first importance in the mountain history. With the exception of some almost unknown deposits (to be mentioned again), from which the Siwalik fossils brought from the Hundes area must be derived, the tertiaries of Tibet are, so far as known, eocene, or, at least, nummulitic. Dr. Stoliczka describes them as very similar to the corresponding deposits of the Sirmúr area in the Simla region: "soft and partly loose conglomerates, reddish and purple slates and marls, and greenish sandstones, much like those on Dagshai hill and to the north of that station" (*l. c.*, p. 343). From these beds at Rámbag, close to the Indus, near Leh, he procured *Nummulites ramondi* and *N. exponens*. In some of the lowest beds of the same group near Kargil, some fossils found by Mr. Drew are mentioned by Dr. Stoliczka as "very like *Melania*, and bivalves almost unmistakably belonging to *Pholadomya* or *Panopæa*" (*l. c.*, p. 348); and he alludes to the beds again as "a brackish and fresh water deposit."[1] The thickness of these strata here is given as 5,000 feet (*l. c.*, p. 348).

According to Dr. Stoliczka's observations, these rocks extend from Kargil on the west, where they end against the syenitic rocks of Baltistán, continuously along the Indus for more than 200 miles to beyond the eastern limits of his explorations. This long trough is seldom more than 25 miles wide, and from end to end a line of eruptive rock accompanies the eocene strata, generally on the south side, but also in the midst of the

[1] Rec. G. S. I., VII, p. 13.

sedimentary rocks, as at the west end about Páskim. Varieties of the eruptive formation are described as epidotic rock, consisting of crystallised or granular masses of epidote, quartz, and albite; also as diallage rock, serpentine, and gabbro. When Dr. Stoliczka first examined these tertiary rocks in Northern Rupshu, the nummulitics are there so indurated, consisting of green and red sandstones and slates, with a thickness of 3,000 to 4,000 feet, that they were taken to be probably a palæozoic series; the eruptive rock also is in great force, being 15 miles wide at the Hánle river, and upon it Stoliczka remarked: "From their dark colours, these rocks have sometimes been referred to the basalts, but they have certainly nothing to do with these more recent volcanic rocks"[1] (*l. c.*, p. 128).

On the north-east side this long compressed basin of tertiary rocks is bounded throughout by the syenitic metamorphic series of the Ladák axis; on the south-west for half its length it is in contact with the Rupshu metamorphics, which thin out gradually, and are replaced to the north-west by the palæozoic slates of the Zánskár basin; and farther on, the nummulitics reach to the triassic outcrop within that basin. Although Dr. Stoliczka found no trace of nummulitic rocks to the south of this very peculiar and well-defined area, he seems to have accepted without hesitation (*l. c.*, p. 354), as of the same deposits, Dr. Thomson's discovery of nummulitics on the Singhi pass (16,600 feet), on the route between Padam and Leh, in the centre of the Zánskár basin. Without presuming to question the possibility of this occurrence, upon so slight a knowledge of the geology of the region, the obvious importance of this observation suggests an examination of its authenticity.[2]

[1] This, of course, refers to the idea, prevalent amongst German geologists until recently, and still held by a large number, that different igneous rocks are characteristic of particular geological epochs. See foot-note, p. 302.

[2] Dr. Thomson's record of the rocks on the Singhi La is as follows ("Western Himalayas and Tibet:" 1852, p. 381): "Quartz rock, slate, and limestone alternated during the ascent; and near the summit of the pass the limestone evidently contained organic remains, perhaps coralline; though their traces were not sufficiently distinct to enable me to decide the point." This observation does not at all suggest an outlying high-level remnant of newer rocks, like those of the Indus valley, but of well-indurated strata, forming the mass of the adjoining mountains. The identification of the fossils is recorded at page 176 of the "Description des Animaux Fossiles du Groupe Nummulitique de l'Inde," by MM. D'Archiac and Haime, as follows: "Un calcaire gris bleuâtre, compacte, pétri d'*Alveolina melo*, associée à une nummulite qui paraît être la *N. ramondi*, a été observé en place par le docteur Thomson, dans la chaîne même de l'Himalaya, au passage et au col de Singhi La, lorsqu'il se rendait de Zanskar à la vallée de l'Indus." There is nothing to suggest doubt or discrepancy in these records; but so great errors of locality amongst the fossils described in this work have been found out (see note, p. 531), that there is room for doubt, where there is anything to suggest it; and it appears desirable that the occurrence of nummulitic rocks on the Singhi La should be verified.

There are no detailed observations to shew the relation of the Indus nummulitics to the contiguous rocks. The facies of the deposits is that of a local basin; and this seems to be the view taken of them by Dr. Stoliczka, at least at the western end; he says: "I rather presume that these beds have been formed in a kind of narrow bay of the tertiary sea, which covered Northern and Eastern Tibet" (p. 348). In his route-notes on his journey to Yárkand, in the same western area, between Shargol and Kharbu, he describes lumps and patches of the triassic limestone sticking out of the tertiary shales.[1]

It seems at least certain from the condition and position of the eocene rocks of the Indus, that vast denudation, and therefore disturbance (*quoad* elevation), of the Himalayan area had occurred in pre-tertiary times. It remains for future observation to shew how far the special disturbance of the older formations corresponds with that which the eocene rocks themselves have undergone.

[1] Scientific Results of the Second Yarkand Mission: Geology, p. 13: Calcutta, 1878.

CHAPTER XXVII.

EXTRA-PENINSULAR AREA.

CENTRAL (TIBETAN) HIMALAYAS—*continued.*

The Hundes or Ngári-Khorsum area — Stratigraphical series of Niti in Hundes — The tertiary eruptive rocks of Hundes — The sedimentary tertiary rocks of Hundes — The Kárákoram area — The Ladák gneiss — The eastern section of the Kárákoram basin — The Kárákoram section — The Kuenlun range — The Suket pass section — The Yángi pass section — The Pámir section — The Kashmir-Pángi area — Triassic rocks of Kashmir — Carboniferous rocks of Kashmir — Silurian rocks of Kashmir — The Pángi basin — The Pir Panjál Chain — One-sidedness of mountain structure — Post-tertiary and recent formations — Sub-Himalayan high-level gravels — Glacial evidence in Tibet — The Hundes lake-basin — Lingzhíthang and Kuenlun lake-basins — Tso Moríri and other basins — Alluvial deposits of Tibet —The Kashmir basin — The Nepál valley — Other lakes — Drainage lines. SUMMARY.

The Hundes or Ngari-Khorsum area.[1]—Although we cannot refer to actual record of the observations, it is probable that the palæozoic series is continuous from the Zánskár basin into that of the Hundes; it is coloured so on General Strachey's map of the Hundes region, no doubt on good authority. It remains for future observation to shew whether the mesozoic formations of the two areas were originally continuous or not; at present they are separated by the gneissic mass of Purgial, against which the Sutlej turns southwards, and which is now the north-western barrier of the present basin of secondary rocks of the Hundes province. At 180 miles to the south-east of Purgial the great Gurla mountain (25,200 feet high), south of Mánasaraur lake, stands right in the axis of the Hundes basin, and may be taken as its limit on this side; although here, too, there is a band of palæozoic and mesozoic rocks passing partially to the south of it, up to the edge of the area explored. Whether continuously or not, it is fairly established that jurassic rocks occur far to the east on this strike, north of Nepál, characteristic ammonites having been brought by traders from that region. On General Strachey's map the gneissic formations of both Purgial and Gurla are shewn to be intrusively penetrated by granite; so we may accept them provisionally as formed of the central gneiss.

[1] Captain Richard Strachey, on the Geology of part of the Himalaya Mountains and Tibet, Q. J. G. S., 1851, Vol. VII, p. 292.

The general aspect of the Hundes area must be very different from that of Zánskár. With the exception of a few small lake-basins, and occasional alluvial patches in the deep river-valleys, Zánskár is covered by lofty rugged mountains, many rising above 19,000 feet, and holding considerable glaciers. The central area of the Hundes is occupied by a great spread of diluvial deposits forming an extensive plateau, 120 miles in length and from 15 to 60 in breadth, at an elevation of from 14,000 to 16,000 feet. It is intersected by great ravines, that of the Sutlej to the west being nearly 3,000 feet deep.

Stratigraphical series of Niti in Hundes.—The numerous collection of fossils made by General Strachey was described by Messrs. Salter and H. F. Blanford, from whose work[1] the subjoined lists are taken; the petrological characters being collected from General Strachey's paper. In most cases the thicknesses are not estimated:—

FOSSILIFEROUS SERIES OF THE HUNDES AREA.

Hard grits, shales, and limestones; no fossils found.

OOLITIC: Dark crumbling shales with hard nodules (Spiti shales), full of fossils; below them are several thousand feet of various limestones (not examined) underlaid by black limestones and shales, with imperfect fossils.

Belemnites sulcatus.
Ammonites acucinctus.
A. alatus.
A. bifrons.
A. biplex.
A. communis.
A. concavus.
A. eugenii.
A. gerardi.
A. griffithii.
A. guttatus.
A. hookeri.
A. heterophyllus.
A. himalayanus.
A. hyphasis.
A. jubar.
A. medea.
A. nepalensis.
A. octagonus.
A. robustus.
A. scriptus.
A. spitiensis.
A. strigilis.
A. tenuistriatus.
A. torquatus.
A. triplicatus.
A. thouarsensis.
A. umbo.
A. wallichii.
Turritella montium.
Pleurotomaria? sp.
Turbo invitus.
Chemnitzia, sp.
Anatina vaginula.
Myophoria blanfordi.
Cardium truncatum.
Cyprina trigonalis.
Astarte major.
A. unilateralis.
Modiola, sp.
Nucula cuneiformis.
Cucullæa virgata.
C. leionota.
Inoceramus hookeri.
Lima acuta.
L. gigantea.
L. mytiloidea.
Monotis concentricus.

[1] Palæontology of Niti in the Northern Himalayas. Printed for private circulation by General Strachey: Calcutta, 1865.

Avicula echinata.	*O. acuminata.*
A. inæquivalvis.	*Terebratula numismalis.*
Pecten æquivalvis.	*T. carinata.*
P. comatus.	*T. globata.*
P. bifrons.	*Rhynconella variabilis.*
P. monilifer.	*R. concinna.*
P. lens.	*Acrosalenia ?*
P. sabal.	*Pentacrinites*, sp.
Ostrea flabelloides.	

TRIASSIC (Upper): Dark-coloured limestone, associated with shales and dark red grits.

Ammonites floridus, Pl. II, fig. 1.	*Natica subglobulosa.*
A. aon.	*Exogyra*, sp.
A. winterbottomi.	*Halobia lommeli*, Pl. II, fig. 5.
A. planodiscus.	*Pecten scutella.*
A. diffissus, Pl. II, fig. 3.	*Lima stracheyi.*
A. gaytani.	*Athyris deslongchampsii.*
A. ausseeanus.	*A. strohmeyeri.*
A. blanfordii.	*Waldheimia stoppanii.*
Ceratites jacquemonti.	*Rhynchonella retrocita.*
Orthoceras pulchellum.	*Spirifera oldhami.*
O. salinarium.	*S. stracheyi.*

CARBONIFEROUS: The rock not identified *in situ.*

Productus purdoni, Pl. I, fig. 10.	*Athyris roissyi.*
P. flemingii.	*Aviculopecten hyemalis*, Pl. I, fig. 13.
Chonetes vishnu.	

SILURIAN[1]: *g.* White quartzite; no fossils.

f. Pale flesh-coloured quartzite; no fossils.

e. Dark-red grits, sometimes marly; with Crinoid stems.

d. Earthy slates and concretionary limestones, *Cyrtoceras, Orthoceras, Chætetes.*

c. Flaggy limestones and grits: most of the Trilobites, *Strophomena, Leptæna, Lituites, Ptilodictyon, Cystidea*, and Fucoids.

b. Limestones and slates: the strong-ribbed *Orthis* (*O. thakil*), *Terebratula, Lingula, Bellerophon*, fragments of *Encrinites*

a. Dark, thick-bedded, coralline limestone.

[1] No plate of the Himalayan silurian fossils has been given in the present work for want of specimens to illustrate. But few have been procured by the Geological Survey, and the figures in Mr. Salter's work are not well adapted for reproduction by lithography. Owing to the rarity of silurian fossiliferous rocks in India and the neighbouring countries, illustrations of the fossils are not of much importance.

The total thickness of these groups is estimated at 6,000 feet.

Asaphus emodi.	*Cyrtodonta ? imbricatula.*
Illænus brachyoniscus.	*Lingula kali.*
I. punctulosus.	*L. ancyloides.*
Cheirurus mitis.	*Leptæna himalensis.*
Prosopiscus mimus.	*L. repanda.*
Sphærexochus idiotes.	*L. cratera.*
Lichas tibetanus.	*L. nux.*
Calymene nivalis.	*Strophomena trachealis.*
Tentaculites, sp.	*S. chamerops.*
Serpulites, sp.	*S. umbrella.*
Nautilus ? involvens.	*S. aranea.*
Cyrtoceras centrifugum.	*S. nubigena.*
Lituites iuliformis.	*S. biserta.*
Orthoceras striatissimum.	*S. halo.*
O. kemas.	*S. lineatissima.*
Theca lineolata.	*Orthis thakil.*
Bellerophon ganesa.	*O. tibetica.*
Murchisonia himalensis.	*O. compta.*
M. pagoda.	*O. monticula.*
Pleurotomaria turbinata.	*O. uncata.*
Raphistoma emodi.	*Ptilodictya ferrea.*
Trochonema humifusa.	*P. plumula.*
Cyclonema rama.	*Sphærospongia melliflua.*
C. subtersulcata.	*S. inosculans.*
Holopea varicosa.	*Chætetes ? yak.*
H. pumila.	*Heliolites depauperata.*
Ctenodonta sinuosa.	

SLATE SERIES: No fossils found; coarse slates, grits, and limestones, with coarse conglomerate of rounded quartzose rocks, at base; 9,000 feet.

METAMORPHICS: Many varieties of mica-schists and gneiss, with beds of highly crystalline limestone and calcareous schists.

From a small collection made by Mr. Hughes, of the Geological Survey, on a trip over the Milam pass, Dr. Waagen has somewhat extended the list of formations in the Hundes basin. The following notes are taken from his paper[1] :—

CRETACEOUS FOSSILS :—*Corbula* cf. *cancellifera; Astarte; Pectunculus; Cucullæa*. The facies of these fossils is considered to be decidedly cretaceous.

JURASSIC FOSSILS :—

Belemnites cf. *kuntkotensis.*	*Ammonites* (*Perisphinctes*), sp. (*triplicatus*, Stol., *non* Sow.)
Ammonites (*Oppelia*) *acucincta.*	*A.* (*P.*) *sabineanus.*
A. (*Perisphinctes*) *frequens.*	*A.* (*P.*) *stanleyi.*

[1] Rec. G. S. I., XI, p. 184.

Ammonites (Perisphinctes), sp.	*Aucella blanfordiana.*
A. (Stephanoceras?) wallichii.	*Au.*, sp., nov.
A. (Cosmoceras) theodori.	*Pecten*, sp.
A. (C.) octagonus.	*Rhynchonella*, sp. (*varians*, Blanf., *non* Schloth.)
Aucella leguminosa.	

TRIASSIC FOSSILS :—A *Monotis*, two *Pecten*, and *Rhynchonella austriaca*, are recognised as of an upper triassic horizon. They occurred in a hard, flaggy, dark-grey limestone. Two fragments of *Ammonites* of the *Am. semipartitus* group, in a smooth, dark-grey, hard shale, are considered as probably belonging to the Muschelkalk, and the Bunter is indicated by a red crypto-crystalline limestone containing a Ceratite like one of the Salt Range species.

PERMIAN AND CARBONIFEROUS FOSSILS :—A white limestone full of crinoid-stems yielded—

Terebratula himalayensis.	*Camerophoria*, sp. nov. ?
T. subvesicularis.	*Productus semireticulatus*
T., sp. nov. ?	*P.*, sp.
Athyris roissyi.	*Bactrynium*, sp.
Spirifer cf. *glaber.*	*Cyathophyllum*, sp.

This fauna is noticed as much resembling that of the lower carboniferous limestone in the Salt Range. A black shale gave a *Rhynchonella*, allied to *Rh. acuminata;* and a dark liver-coloured limestone contained *Spirifer* cf. *striatus; Stringocephalus ?* sp.; *Rhynconella ?* sp.

SILURIAN FOSSILS :—A white sandstone yielded *Strophomena aranea.*

The crystalline schists (central gneiss) at the edge of the Hundes basin are profusely penetrated by a coarse, white granite, with much schorl and kyanite. All the great peaks of the snowy range occur in this zone. The summits of the highest passes, which average about 18,000 feet in elevation, are in the zone of palæozoic rocks, which rise into peaks some 2,000 feet higher than the passes. A northerly dip is constant throughout the whole stratified series; and no unconformities were detected. General Strachey considers that the south edge of this basin has probably been a sea margin from the remotest ages of the earth's history (*l. c.*, p. 308).

The tertiary eruptive rocks of Hundes.—There can scarcely be a doubt that the igneous rock so conspicuous at various points of the Hundes area is the same as, and probably continuous with, the middle tertiary (or at least post-nummulitic) eruption of the Indus valley in Ladák and Rupshu (p. 643). General Strachey describes a great outburst of this rock, 35 miles wide, "in which are found hypersthene and bronzite, besides syenitic and ordinary greenstones, and various varieties of porphyry," forming the western shores of the Rákas Tál, which is the western companion of the Mánasaraur (Manasarowar) lake; and from here

the trap seems to extend in force to the north-west, on the north side of the Hundes plain. The intrusion is not, however, so restricted to this main line of eruption as it seems to be in Ladák; for General Strachey has mapped several detached protusions of the same rock, notably that forming the Bálch pass, surrounded by jurassic strata. Others appear surrounded by the Hundes plains deposit, and it would seem in the figured section that the trap penetrates, and now overlies, these very new rocks. This error of drawing is sufficiently corrected in General Strachey's text, where, in a paragraph of the summary, it is distinctly stated that the tertiary beds of the plains were deposited upon and contain debris of the eruptive rock. The jurassic strata being the latest known to be affected by the intrusive rock here, this has been taken as a lower limit of age for the eruption, and the supposed tertiary deposits of the plains have given an upper limit of date. The correlation of the rock with that of Ladák reduces the question of its age to much narrower limits, as middle tertiary.

The sedimentary tertiary rocks of Hundes.—The earliest evidence, so far as known, of tertiary rocks in Tibet, came from the Hundes area. In the first quarter of the century, long before the discovery of the Siwalik fossils, fragmentary remains of extinct mammals from beyond the Niti pass were brought to notice. Specimens were even presented to the Geological Society of London about that time by Sir Thomas Colebrooke and Dr. Traill; others were sent to the British Museum. But from that time till now they have received little or no attention, probably on account of their fragmentary condition, and because nothing precise was then known as to their geological position. General Strachey to some extent removed this latter objection (*l. c.*, p. 306), by declaring that these fossils were derived from the great undisturbed diluvial deposits filling the upper valley of the Sutlej to a depth of 3,000 feet, and forming the wide plain of Hundes. He also enumerates some approximate determinations of the specimens he collected himself, made at his request by Mr. Waterhouse: there were—bones of *Hippotherium* (*Hipparion*); of several varieties of horse; of a bovine ruminant; a head allied to goat or sheep; a vertebra of rhinoceros; tooth of elephant (?). The evidence is not sufficient for correlation with any precise horizon; the fauna is, however, an extinct one, and may perhaps be relegated to some place in the great Siwalik series.

General Strachey did not, however, omit to state that none of his specimens were found *in situ*, and that, in spite of every attempt, he could not hear of a definite locality in which any one knew positively that they had been found. His own conviction as to their being derived from the horizontal plain's deposits is based on their general position, supported

by the fact that on many of the specimens there are attached remnants of a fine calcareous conglomerate, exactly identical with beds observed intercalated with the boulder and gravel-beds that constitute the mass of the deposits. This point cannot be much insisted on; for the complete similarity of such rocks in different groups is well known (p. 555). Any shadow of doubt upon the correctness of this inference comes principally from the asserted horizontality of these deposits, whereas the latest Siwalik beds in the Sub-Himalayan zone are locally vertical; and even some doubtfully tertiary deposits in the Kashmir and Nepál valleys (to be mentioned in our brief notice of the Himalayan post-tertiaries) have suffered some disturbance. It should be noticed that the occurrence of a displacement of the Hundes deposits seems to have been contemplated by General Strachey; for he speaks of some similar deposits, to the south of the Niti pass, as having been separated from the general mass by the dislocations that have upheaved the whole country (*l. c.*, p. 308). These discrepancies are noticed with a view to verification by future explorers: it may be that beneath the general mass of undisturbed diluvium forming the Hundes plains, there may occur obscure outcrops of similar deposits, of much older date, that have undergone considerable disturbance. The comparative antiquity of even the most recent beds of the Hundes plain seems to be attested by the existence of ancient moraines upon that plain (*l. c.*, p. 310). These deposits will be referred to again with others of a like nature.

The Karakoram area.—Dr. Stoliczka's observations on this ground were taken under very trying circumstances, while making forced marches at a most unseasonable time of year. His outward route lay by the Pángkong, Chángchenmo, Lingzhíthang, and the Upper Kárakásh valley. His return journey lay more to the west; his last march but one was across the Kárákoram pass.[1]

The Ladak gneiss.—The entire ridge north of the Indus consists of syenitic gneiss of extremely variable composition. The typical rock is a moderately fine-grained syenite, with veins richer in hornblende; some portions contain much schorl. In finer varieties the felspar almost disappears, and the quartz is very scarce, forming a hornblende schist. In places the hornblende disappears, the crystals of felspar increase in size, and with mica (biotite) and quartz form an ordinary gneiss, but inseparable from the syenite, to which it is subordinate. To the north the syenitic gneiss passes into hornblende and chlorite schists, alternating with quartzose schists of great thickness. These rocks extend to the

[1] Rec. G. S. I., VII, pp. 12 and 49; also, Scientific Results of the Second Yárkand Mission: Geology: Calcutta, 1878, pp. 15-20, and 45, 46.

Lunkar-la or Másimik pass. They are intimately connected with a greenish chloritic rock, both thin-bedded and more massive, the latter sometimes distinctly crystalline, containing bronzite, and passing into diallage. These beds are compared to those found about Srinagar, in Kashmir (Mr. Lydekker's silurian trappean group); they occupy the south-west side of the Chángchenmo valley. On the western route similar rocks were traced, by Dr. Bellew, up the Nubra valley to near the foot of the Saser pass. Dr. Stoliczka says: "I think we have to look upon this whole series of schistose and chloritic rocks as the representatives of the silurian formation." The remark seems to include all the rocks of the Ladák range; but this is not certain, for a little further on in the same short paper the Kárákoram area is spoken of as bounded on the north and south by syenitic rocks, including between them the silurian, carboniferous, and triassic formations. The Ladák gneiss is so unlike the description given (by the same observer) of the gneiss of Rupshu (*ante*, p. 640), where also the silurian formations are unrepresented, unless by the crystalline schists, that we may expect some radical difference between them; it may be that the central gneiss is largely represented in Rupshu. The two areas are separated by the trough of tertiary rocks, sedimentary and eruptive. A northerly dip seems to be as general in the Ladák gneiss as is the southerly one in Rupshu; so that the tertiary basin would seem to lie on the axis of a great anticlinal, in contact with the very lowest rocks of the Central Himalayas.

The eastern section of the Karakoram basin.—The observations made on the eastern traverse of the Kárákoram basin differ in so many points from those of the western route, that they are better given separately. The direct length of the former section on a line north by west, from the top of the silurian rocks at the Chángchenmo river to the Kuenlun gneiss near Sháhidula, is about 120 miles. The length of the western section in a north-north-east direction, from a corresponding point near the Nubra river, below the Saser pass, to Sháhidula, is about 90 miles, which is also nearly the distance between the two starting-points.

The passage from the trappoid silurian rocks south of Chángchenmo was not observed; but on the north side of the valley there are dark, often black, shales with sandstones. Traces of fucoids were found in these rocks, but no other fossils; from their relation to the triassic limestone, and their resemblance to the carboniferous rocks of Spiti, the beds are supposed to be carboniferous. Obscurely connected with these beds, near Kium, in the Chángchenmo valley, some recent-looking conglomeratic sandstones are noted as possibly related to the eocene deposits of the Indus valley.

The carboniferous series must be of considerable thickness, for it forms the Cháng ridge, north of the Chángchenmo valley, and the whole of the western portion of the Lingzhíthang; occurring again at the head of the Kárakásh river as far as Shinglung. Similar rocks were observed by Dr. Bellew on both sides of the Saser pass, and to the north of it. There is no mention of a calcareous rock in any of these sections.

A pale-grey triassic limestone, containing *Dicerocardium himalayaense* and *Megalodon triqueter*, occurs within the Chángchenmo valley, and is the most frequent rock, forming the ridges to the north. It is sometimes dolomitic and semi-oolitic, and is locally underlaid by a red brecciated calcareous conglomerate. On the border of the Lingzhíthang it is said to rest unconformably on the carboniferous shales. The last place where this triassic rock was observed was also at Shinglung, near the head-waters of the Kárakásh.

On this route Dr. Stoliczka observed no newer rock than the trias; but, as before mentioned, the ground was covered with snow at the time, and the difficulties of the journey were extreme. A little to the east, however, in the Lokzhung range, separating the Lingzhíthang plains from the larger area on the north, described by Mr. Drew as the Kuenlun plains, the last-named observer found a limestone containing hippurites, underlaid by ferruginous sandstone, lying unconformably on an older encrinitic limestone, dark grey in colour.[1]

At Shinglung, in the Upper Kárakásh valley, the carboniferous shales are followed immediately by the same chloritic rock noticed on the Lunkar-la, alternating with quartzose schists, and there regarded as silurian. At Kisiljilga ordinary slates alternate with red conglomeratic sandstones, and are succeeded by dark slates, which rock is described as occupying the ground to Aktágh, and thence across the Suget-la to near Sháhidula, on the Kárakásh, where the syenite of the Kuenlun begins. These silurian slates are expressly noticed as not metamorphic, and as corresponding with the metamorphic schists on the side of the Ladák axis.

The Karakoram section.—By the eastern route, Dr. Stoliczka approached Aktágh nearly from the east, and left it in a north-east direction; and the observations recorded are strikingly different from those made on the route from the north-west, and proceeding south-south-west to the Kárákoram pass. On the former route no mention is made of limestone anywhere near Aktágh; while on the latter limestone is by far the most conspicuous rock. Some miles below Aktágh, towards the Yárkand

[1] Jummoo and Kashmir, p. 343.

river, the silurian slates are overlaid unconformably (in the figured section they are quite parallel) by about 150 feet of reddish earthy and calcareous sandstones, passing into grey limestone and whitish marl, some 550 feet thick; higher beds are reddish and brownish, sandy and conglomeratic. No fossils were found in these rocks; but they are considered as probably carboniferous, and to be continuous from here with the similar rocks observed at Aktásh, east of the Pámir. At Aktágh there are some earthy and conglomeratic beds, resting on the edges of the carboniferous strata, and themselves considerably disturbed; they are conjectured to be tertiary. Proceeding towards the Kárákoram, the carboniferous rocks are regularly overlaid by a long sequence of triassic strata, dark and pale limestones and shales. A red limestone yielded *Arcestes johannis austriæ (?)*, *Ammonites batteni*, *Aulacoceras*, and Crinoids. Both carboniferous and triassic rocks are frequently traversed by a dark homogeneous greenstone, resembling basalt. At the Kárákoram the red triassic limestone is succeeded by blackish and grey marly shales which are overlaid by almost horizontal strata of brown limestone, very like the lower Tagling limestone, and containing fragments of *Belemnites*. These triassic rocks form the ridge at the Kárákoram pass. Some peculiar spheroidal fossils, known as Kárákoram stones, were observed to occur in dark shales below limestone taken to be triassic. They were described as Cystideans formerly, and have since been considered by various observers sponges or corals, but they appear to be types of a distinct class of animals, *Syringosphæridæ*, allied to the *Foraminifera*.

In his last day's notes Dr. Stoliczka records the occurrence of large boulders of syenite on the Dipsang plain, immediately south of the Kárákoram pass; and he draws the apparently obvious inference that this rock must be exposed *in situ* within the watershed, the extreme point of which at the head-waters of the Chipchak stream is only 25 miles to the east, and thus in the very centre of the stratigraphical basin. The route by the upper Kárakásh and over the Káratágh passed much closer to the upper Chipchak, on the east and north ridges of the same mountain crest, without any observation to suggest the proximity of crystalline rocks; so it is not impossible that the blocks in question may be true erratics, traces of the former extension of glacial conditions, of which almost every traveller in the Himalayas has made mention.

The Kuenlun range.—Dr. Stoliczka has given two sections of the Kuenlun; one on the west by the Yángi pass, and one fifty miles more to the east by the Suket pass, with which we must combine that of the Sánju pass on the same cross-section, over the northern or Kilián ridge of the same range.

The Suket pass section.—The relation of the slates forming the Suket pass, supposed to be silurian, to the syenitic gneiss, alternating with quartzose metamorphic schists to the north of it, in the Kárakásh valley about Sháhidula, is not stated. It is in these gneissic rocks that the old jade mines are placed, at about 20 miles up the Kárakásh, east-south-east from Sháhidula; and the gorge of the river, for 25 miles below Sháhidula, to the north, traverses the same formation. On the Sánju pass the rock is chiefly a true mica-schist, with garnetiferous, chloritic, and quartzose varieties, in which jade was observed. In the Sánju valley, at Tám, some 20 miles north of the pass, the metamorphic schists are overlaid unconformably by dark, almost black, smooth slates, succeeded by grey conglomeratic sandstone belonging to some palæozoic formation. These dip at 40° to the north-west, but are again abruptly replaced by metamorphic schists, in which occur several massive beds of coarse porphyritic gneiss; these continue for 18 miles, to Kiwáz. At Kiwáz both sides of the valley are formed of conglomerates and red clays, said to strikingly resemble the supra-nummulitic rocks of the Sub-Himalayas and supposed to be tertiary. These have undergone contortion; and below Kiwáz they rest upon thick grey carboniferous limestone, containing Crinoid stems, Spirifers, and *Fenestellæ*. The dip in this rock is to the south-west, rising to the vertical, when it is succeeded by chloritic schist, which, after a mile or two, is in contact with red sandstone; and this again, at Sánju, is overlaid by calcareous sandstones and chloritic marls, some beds of which are nearly made up of *Gryphæa vesicularis* (*? vesiculosa*). This cretaceous group of Sánju is represented in the figured section with a low northerly dip, running up against the schists to the south, which somewhat reduces the difficulties of this rather anomalous sequence.

The Yangi pass section.—The second section of the Kuenlun corresponds only in a general way with that to the east. Some distance north of the pass there is a broad core of white granitoid gneiss, which is spoken of as the axis of the whole metamorphic mass. It is overlaid on both sides by schistose gneiss; and on the south this is overlain by black shale, grey sandstone and conglomerate, the whole series being spoken of as upper palæozoic. The coarse conglomerates are in great force at the Yángi pass (16,000 feet), and have a comparatively recent aspect, evidently forming the top of the series. They are identified with the beds at Tám, on the Sánju section. The lower, greenish and blackish, submetamorphic slaty or schistose beds turn up again south of the pass; and it is upon these that the newer rocks rest, as already described, near Aktágh. It must be remembered that all these details are derived

from uncorrected field-notes; and it is quite possible that had Dr. Stoliczka lived to publish his observations, he would have corrected them in many cases.

North of the gneissic axis there is a broader belt of metamorphic rocks, chiefly of a syenitic (hornblendic) character; and for a width of 16 miles the section is occupied by massive greenstone, which on the north is described as if, in part, a transformed condition of a bedded chloritic rock. This latter rock, with alternating white quartzose and calcareous schist, forms the Chiklik pass (10,400), at the north base of which it is succeeded by a thin-bedded limestone, also affected by metamorphism. This limestone increases to a great thickness, forming a belt some miles wide between the Chiklik pass and a point about 12 miles south of Kugiár. There is a reddish sandy band in the middle of it. The limestone itself is spoken of as grey dolomite. The dips are high and disturbed, but the prevailing direction is to the north. No fossils were found, and no suggestion is given as to the age of this limestone: it is presumably either carboniferous or triassic. No cretaceous beds were observed on this section.

The Pamir section.—A brief note of the section of the Pámir will be of interest, for comparison with those of the Himalayas proper. The direct distance in a west-south-west direction is about 220 miles from Ighiz-yar, at the edge of the Yárkand plains, at an elevation of 5,600 feet, to Kila Panjah, the capital of Wakhán, elevation 9,090, on the Oxus, at the confluence of the two western streams, from the Great Pámir on the north (elevation 14,320), and from the Little Pamir on the south (elevation 13,200). The drainage of the eastern side of the Pámir also flows to the Oxus, by the Aksu river (probably the original of Oxus) passing by Aktásh, elevation 12,800 feet. The main watershed lies close to the east of Aktásh, at the Nezatásh pass, elevation 14,900 feet, at about the centre of a synclinal basin, between the gneissic axes of Sarikol and the Pámir. The Pámir is placed at the apex, where the Mustágh and Hindukúsh ranges would meet, at an angle of about 120°, if prolonged on their general directions; but on the maps these ranges are represented as swerving southwards from the Pámir, and as being confluent in the range from which the Gilgit river flows south-eastwards and the Chitrál flows south-westwards, the pass to the latter valley from the Oxus having only 12,000 feet of elevation.

The mass of the Pámir is mainly formed of gneiss; a pale, fine-grained, mica-gneiss, which Dr. Stoliczka considered to be the same as the central gneiss of the Himalayas. It exhibits comparatively little disturbance, and is locally traversed by veins of albite granite, with mus-

covite. It is not distinctly stated whether this granite is intrusive. The correlation of this gneiss with the central gneiss is supported by the fact that the former is at many points immediately overlaid by black slates and shales, probably silurian, shewing very little alteration at the contact. The slates pass up into reddish sandy and conglomeratic beds. On the north-east, towards Aktásh, these rocks are overlaid by some 3,000 feet of limestone, both dark and pale varieties, considered as probably carboniferous; and these are succeeded by dark shales and limestone, in which, on the Nezatásh pass, *Halobia lommeli*, *Rhynconellæ*, and *Megalodon* were found, proving the triassic age of the rock. East of this the black silurian slates turn up, with a very steep underlie, and are thus in abrupt contact with the gneiss of Sarikol. The width of the Aktásh basin, between the two gneisses, is less than 50 miles. Intrusive greenstone is of frequent occurrence in the highest beds, as we have seen in the Kárákoram section, south of Aktágh. The Aktásh basin is, in fact, considered by Dr. Stoliczka to be the stratigraphical continuation of the Kárákoram.

The abrupt boundary of the Sarikol gneiss with the rocks of the Aktásh basin is probably faulted; for the relation of the same gneiss to corresponding beds on its north-east side is described as transitional, the palæozoic strata having undergone considerable metamorphism; and the gneiss itself is largely hornblendic and much disturbed. The Sarikol gneiss is about 25 miles broad, and is held to correspond with the crystalline rocks of the Kuenlun axis. Along the whole section to the north-east, 50 miles long, only lower palæozoic rocks were observed *in situ*; slates and sandstones, occasionally conglomeratic and earthy limestone, all without fossils; but debris of carboniferous limestone, with *Bellerophon*, was found in the lateral stream courses. Between Aktala and the gneiss there is extensive irruption of greenstone, like that south of Chiklik, on the Yángi section. The degree of disturbance diminishes in a very marked manner towards the plains.

The Kashmir-Pangi area.—This ground includes, as already indicated (p. 626), a pair of semi-detached synclinal basins, on the same strike, south of the Zánskár ridge, which is in elevation the principal continuation of the main Himalayan range. The Kashmir area coincides nearly with the upper basin of the Jhelum, and the Pángi area may be taken to indicate the upper valley of the Chináb, from the head-waters in Láhul to below Kilár. The irregular chain of ridges described (p. 631) as the Pir Panjál forms the south side of these basins; and the minor basin on the upper Rávi, in Chamba, between the eastern Pir Panjál and the Dhauladhár, belongs to the same group of terminal

features, on the divided prolongation of the main range. The following approximate classification of rock-groups in this ground is taken from Mr. Lydekker's paper[1] :—

Kashmir and Pángi areas.	*Areas to north and east.*	*Age.*
a { Sandstones and slates of Zoji-la and Panjtarni. b { Upper limestones and dolomites of Amrnáth, Sonámarg, Mánasbal, and Drás river.	Liláng series.	Rhætic and trias.
Limestones of West Kashmir. Blue limestones of Mánasbal. Limestones and slates of Marbal pass, Lidar and Upper Sind valleys, Kiol series (?). Great limestone of Jamu hills (?).	Kuling series. Król limestone (?) *Infra*-Król group (?)	Carboniferous.
Upper Panjál slates, shales and trappoid rocks. Trappoid rocks of Walar lake.	Muth series. Blaini series.	Upper silurian.
Lower Panjál slates; lower slates and trappoid rocks of Kashmir. Slates and limestones of Pángi, Láhul slates.	Bhábeh series. *Infra*-Blaini, or Simla slates.	Lower silurian and Cambrian (?).
Gneiss of Pir Panjál. Upper gneiss of Wardwan and Záuskár range.	?	Cambrian.
Central gneiss of Dárcha. Lower gneiss of Wardwan and Záuskár range. Dhauladhár gneiss.	Gneiss of Wángtu and Chor mountain.	*Infra*-silurian, but exact age not determined.

For convenience and clearness, we must again make a local exception to our rule, and describe the formations in descending order.

Triassic rocks of Kashmir.—As already mentioned (p. 631), the sedimentary series of the Záuskár basin, from the trias downwards, rolls over into the Kashmir basin, round the termination of the great gneissic mass of the Zánskár range. Although the feature is thus in the main a great anticlinal, the very crest of the ridge, at the Zoji-la, is formed of a sharp and locally inverted synclinal, in the highest rocks of the local series. It was this inversion that led Dr. Stoliczka to suppose that the sub-schistose sandstones at the Zoji-la were carboniferous, from

[1] Rec. G. S. I., XI, p. 63.

their apparently underlying triassic strata. Mr. Lydekker found the same rocks to the south-east near Amrnáth and Panjtarni to be distinctly folded in a trough of the dolomitic limestone. The age of these limestones is well fixed north of the Zoji-la. Dr. Stoliczka observed a great thickness of light-blue limestone forming the banks of the Drás river, and containing numerous small bivalves, like *Megalodon columbella*, Hornes, from the upper trias of the Alps. It is overlaid to the south by a darker dolomitic limestone, apparently identical with the Pára limestone of Northern Zánskár. South of the Zoji-la, Dr. Stoliczka found *Ammonites gerardi* in the limestones and carbonaceous slates near the camp Thájwaz in the Sind valley, proving them to belong to the Liláng group of Zánskár.[1] There would seem, however, to be great variability in the composition of these groups. Mr. Lydekker (*l. c.*, p. 45) identifies the white dolomite of Amrnáth with the Pára limestone north of the Zoji-la; and in the Chandanwarí section (*l. c.*, p. 44), at the head of the Lidar valley, a set of slates and sandstones separates these white dolomites from the dark-blue carboniferous limestone, and is interstratified with both of them. This apparent transition between carboniferous and uppermost triassic strata calls particularly for further examination. Triassic rock has as yet only been observed in one other locality in the area under notice; it is in the Kashmir valley, in the promontory south of the Mánasbal lake, where the white dolomite overlies the compact blue carboniferous limestone.

Carboniferous rocks of Kashmir.—With the exception of the very local occurrence of the triassic limestone on the north side of Kashmir, as already mentioned, only palæozoic and gneissic rocks are found throughout the rest of the area under notice, in which condition this ground exhibits a partial affinity with the Lower Himalayan area. Of the palæozoics, again, only the upper members have been fully recognised by fossil evidence; and in this way they have scarcely been traced beyond the limits of Kashmir, where they are almost confined to the north side of the valley. We must notice these rocks first, as it is through comparison with them that the position of other groups has been provisionally determined.

The identification of carboniferous rocks in Kashmir is of old standing. Fossils are locally abundant, but no large collection of them has been made. The following species of carboniferous *Brachiopoda* were described by Mr. Davidson[2] from specimens collected by Captain

[1] Mem. G. S. I., V, p. 349.
[2] Q. J. G. S., XXII, 1866, p. 39.

Godwin-Austen near the villages of Khunmu, Bárus, and Zewán, in the Vihi valley, immediately to the east of Srinagar :—

Terebratula sacculus.
Athyris subtilita, Pl. I, fig. 4.
Spirifera keilhavii, Pl. I, fig. 1.
Sp. vihiana.
Sp. kashmiriensis.
Sp. moosakhailensis, Pl. I, fig. 2.
Sp. barusiensis.
Rhynconella barumensis.
Rh. kashmiriensis.
Streptorhynchus crenistria, Pl. I, fig. 7.
Productus semireticulatus, Pl. I, fig. 8.
Pr. scabriculus.
Pr. humboldtii.
Pr. spinulosus.
Pr. lævis.
Chonetes lævis.
Ch.? austeniana.
Discina kashmiriensis.

Two measured sections from this neighbourhood by Captain Godwin-Austen[1] will shew the local composition of the series. The fossils were principally found near the very base of the formation; and it would seem from his figured sections that the bottom quartzite is unconformable to the underlying hornblende slates; but as no statement is made to that effect, the point is doubtful. The appearance is probably due to the locally unstratified condition of the trappean upper silurian rocks.

Section along a spur from Wasterwán, between Bárus and Reshpur.

	Feet.
8. Hard compact limestone, weathering light ochre	100
7. Hard compact limestone, no fossils	110
6. Grey limestone, weathering light-brown	200
5. Micaceous sandy limestone; *Spirifera rajah*, and *Productus semireticulatus*	60
4. Slaty shale	15
3. Shaly limestone, weathering green, full of fossils	40
2. Hard fossiliferous limestone	80
1. White quartz rock	15
Hornblende slate	
	920

Section at the foot of a ridge from Zhanwán.

	Feet.
7. Hard compact crystalline limestone, of a dark blue-grey, interstratified with grey shales, which weather to a green tint, very fossiliferous	20
6. Calcareous shales, very fossiliferous	30
5. Alternations of shaly slate and sand	30
4. Sandstone containing water-worn pebbles	2
3. A bed of water-worn pebbles and shingle, of quartz and hornblendic rock, imbedded in a sandy crumbling matrix	4
2. Altered sandstone and shaly beds, very hard and splintery	15
1. White flinty quartzite	12
Hornblendic slaty rock	
	83

[1] Q. J. G. S., XXII, 1866, p. 29.

Owing to the excessive disturbance all these strata have undergone, and the deep erosion of the ground, the upper members of the stratified series are only found in isolated masses along the inner edge of the valley, and in the hills to the north. No carboniferous rocks have been observed on the south-west side of the valley, on the flanks of the Pir Panjál; but at the south-east end of the valley, south of Sháhábád, the rocks of the Pir are in faulted contact with the mass of carboniferous limestone, which here closes the valley, and stretches for a few miles beyond the watershed at the Marbal pass. The general structure is that of a broad complex synclinal fold, the axis rising to the south-east. At the north-west end of the valley also, at Trigamma, the carboniferous limestone is in force, occupying a synclinal fold in the slates. Near Sháhábád Mr. Lydekker describes the sequence as consisting of dark-brown sandy shales, gradually becoming calcareous, and so passing up into the characteristic dark-blue carboniferous limestone, which is over-laid by yellowish and whitish sandstones. These highest beds are often replaced by banded limestone, and may represent the trias.

From the examination of many sections, Mr. Lydekker concluded that the carboniferous rocks are normally in conformable sequence with the underlying slate series. This relation is seen in the section near Eishmakám, in the Lidar valley, north of Islámábád, where the following beds are in regular succession, No. 1 being silurian and Nos. 2, 3, and 4 carboniferous:—

4. Slates and sandstones with *Fenestella*, *Productus*, and *Spirifera*.
3. Sandstones and dark-blue limestones, with corals and crinoids.
2. White and blue sandstones.
1. Blue or green slates and amygdaloids.

The proportion of limestone in the carboniferous series is very variable in different sections.

Silurian rocks of Kashmir.—It is upon the strength of this close connection with the carboniferous strata that the underlying series is taken to be silurian; for not a single fossil has been found in these rocks throughout the whole of this region. They are, however, continuous with rocks in corresponding relations to the carboniferous group in Zánskár, where silurian fossils do occur (p. 638), though far less abundantly than farther east in the Hundes basin (p. 649). The absence of organic remains is only very partially accounted for by the greater metamorphism of the strata in the north-western area.

Another cause of doubt regarding the correlation of the different formations in Kashmir has been the extensive occurrence of trappean rocks, and the uncertainty as to their relation to the sedimentary series,

and, therefore, as to their age. All the rocks have been so contorted, that special examination was needed to distinguish effects of irruption from those resulting from a disturbance common to all, the local appearances being superficially very deceptive : thus north-east of Mánasbal there is a dome-shaped mass of amorphous greenstone, with the carboniferous limestone dipping from it on three sides. Such appearances are very suggestive of intrusion; and so the prevailing opinion has been, that the trap of Kashmir and the Pir Panjál is of later date than all the contiguous formations. Mr. Lydekker, however, comes to the conclusion that the trap is altogether pre-carboniferous, no single instance of true intrusion having been found; and the general distribution of the rock clearly points to its cotemporaneity with the upper silurian strata.[1] In Northern Kashmir, especially about Srinagar, Mánasbal, and the Walar lake, the massive amorphous forms of greenstone are predominant; but even with these there are associated stratified earthy and amygdaloidal beds, identical with those which all through the Pir Panjál and elsewhere are characteristic of the upper zone of the slate series. To a great extent these beds are of a mixed nature, containing much silicious detrital matter with the trappean ingredient, and their trappoid character is further to some extent due to partial metamorphism; but there can scarcely be a doubt that the peculiar facies of the upper silurian zone of this region (and it seems to extend also to the western part of the Zánskár area) is due to cotemporaneous eruptive action. The following general sequence of the strata composing the lower palæozoic rocks, forming the slate series, is taken by Mr. Lydekker (*l. c.*, p. 39) from the section of the Pir Panjál pass :—

5. Greenish slates, sandstones and amygdaloidal rocks.
4. Black and green slates with brown sandstone conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
2. Black slates containing pebbles of gneiss and quartzite.
1. Granitoid gneiss, with occasional bands of slate and quartzite.

The relation of the palæozoic slates to the crystalline series is a point of special interest and difficulty, as has been shewn in other cases (p. 640). In the region under notice Mr. Lydekker has found this relation to be one of inseparable association, as is indicated in No. 1 of the preceding section of the rocks in the Pir Panjál. The same condition obtains on the north-east, with reference to the gneissic mass of the Zánskár range; as is well

[1] Dr. Verchère (J. A. S. B., XXXV, 1867, p. 86) had announced the same conclusion; but this writer's views are not always supported by sufficient evidence to be accepted.

seen in passing from the south-east end of Kashmir, by the Margan pass, to the Wardwan, and down the latter valley to Kishtwár. It is not merely a case of gradual transition of metamorphism, but also complete association by interstratification of slaty and gneissic rocks, and their equal participation in the results of disturbance. Some of the bands of gneiss thus intercalated with the slates are quite massive and granitoid, both fine-grained and porphyritic. The contrast is altogether most striking between this mode of relation and that of the slates to the central gneiss of the Lower Himalayan region; and the inference is, that the gneiss of Zánskár is to a great, but unknown, extent made up of converted palæozoic strata. Abrupt contact is here also found between the two types of rock; but they are more or less distinctly due to dislocations, as at Krur in the lower Wardwan valley.

The Pangi basin.—Below Kilár, the gneissic rocks of the Zánskár ridge pass well to the south of the Chináb; and it is not known whether they are not there confluent with the gneiss of the Pir Panjál chain, thus separating the slates of Pángi from those of Kashmir. There can scarcely be a doubt that these two belong to the same lower palæozoic series; but there are some noteworthy differences of composition. The trappoid rocks have not been observed in Pángi; it may be because the eruptive action did not extend so far, that zone being represented by ordinary slates; or, only the lower members of the series may be represented in Pángi. Bands of limestone are not very rare in the Pángi slates, although entirely wanting in the Kashmir area. The quasi-erratic boulders in the black slates of Pángi, as already mentioned (p. 632), are very peculiar; although these slates are probably the local representatives of the zone No. 2 of the Pir Panjál section in the list already given. The relation of the slates to the gneiss in Pángi is not exclusively like that described in the Wardwan valley: in introducing the Pángi slates, Mr. Lydekker (*l. c.*, p. 54) describes a very thick band of granitoid gneiss as conformably overlaid by a newer series of bluish slates and sandstones, which contain no truly metamorphic rock. At the east end of the basin, the junction of the slates with the gneiss of the Rotáng pass would seem to be of the same abrupt kind. Yet on a parallel section to that at Kilár, about Tingrat, in the valley north of Triloknáth, there is an alternating passage from the slates to the gneiss. It is by the close comparison and connected survey of such contrasting sections, that we may ultimately expect to separate the two very distinct gneissic formations, which we are almost forced to think must be present in this ground (p. 630): the central gneiss, of long pre-silurian metamorphism; and a lower silurian or cambrian gneiss, made out of, and

associated with, deposits that have undergone little or no change in adjoining areas.

The Pir Panjal chain.—The extension already given (p. 631) to this name of the range outside (south-west of) Kashmir, to include the ridges in approximate continuation of it to the south-east, although separated by the gorge of the Chináb below Kishtwár, may be upheld geographically; but geologically (as based upon structural equivalence) it is still provisional, for we have no observation of these hills south of the upper Chináb valley. So far as we know, the slates of Pángi may be continuous with those of the upper Rávi valley, without any dividing gneissic axis. In this south-eastern ground, too, the range in question is not the outermost range of the older formations, for the Dhauladhár lies to the south of it; and it may be to this condition, of an outside position in the mountain system, that is due the peculiar structural character noticed in the Pir Panjál and Dhauladhár ranges—that of a great folded flexure, with inversion on the outer side. This peculiarity is, perhaps, opposed to the connexion of this ridge with the central region, of which it is thus here a specially marked marginal feature. Its affinities are, however, much closer with the area of normal Himalayan disturbance, than with the Lower Himalayas, where the structure is quite different (p. 602).

Mr. Lydekker has clearly shewn this structural character at the Banihál pass,[1] and at the Pir Panjál pass[2]; and the same feature had previously been noticed in the Dhauladhár.[3] In proceeding from Kashmir across the Pir Panjál pass, the sequence of rocks given above (p. 663) is observed in descending order, the beds dipping towards the valley. The dip increases steadily, and becomes vertical in the gneiss; then the black slates (No. 2), with pebbles of gneiss, come in again, but with a steep underlie towards the gneiss; and they are succeeded at the crest of the pass by the white quartzites, having the same inward dip; under these again come the greenish trappean beds of zone No. 4; the whole series, many thousand feet in thickness, being clearly inverted on the south side of the axis.

On the outer margin of the range, in the inverted series, higher (apparently lower) beds are preserved than on the side next the valley. They consist principally of limestone, with a variable proportion of associated black and greenish shales and pale sandstones. From their conformable and transitional relation to the trappean upper silurian zone,

[1] Rec. G. S. I., IX, p. 161, 1876.
[2] Rec. G. S. I., XI, p. 39, 1878.
[3] Mem. G. S. I, III, Pt. 2, p. 63, 1864.

Mr. Lydekker concludes that they represent the similar, but fossiliferous, rocks in a like position in Kashmir, and are therefore carboniferous. This band of limestone is more or less continuous at the edge of the higher mountains, from the Pir Panjál to the Lower Himalayan area; and it is upon this remote and slender connexion that the Król limestone, capping the slate series in the Simla region, is taken to be carboniferous. The identification of the great limestone, forming the large inliers of the Sub-Himalayan zone (p. 562), from 4 to 12 miles distant from the base of the Pir Panjál, as carboniferous, is perhaps equally open to verification. If all the limestone of those inliers is carboniferous, the deposits of that age increased enormously in thickness within a very short distance; but this inequality of deposition has been very generally observed in the carboniferous rocks of the Himalayas.

The fact that the gneiss partakes so regularly in the disturbance of the slates, would seem necessarily to imply original complete conformity of stratification between them; and therefore the probability is, that all the metamorphics of the Pir Panjál belong to the newer gneiss. It may also be suggested that this form of disturbance, a great regular folded flexure, could hardly have occurred here had there been a primitive ridge of old gneiss occupying the position of the present axis; from which we may suppose, that if the central gneiss is represented here, its elevation is altogether due to post-silurian disturbance.

There are, however, certain irregularities in the feature as a whole, that necessitate some modification of the view of it as a single and simple anticlinal flexure. The outcrop of the core of gneiss is not continuous; nor does it observe a strictly uniform direction throughout. These irregularities, moreover, are not superficial; thus, in the deep gorge cut by the Jhelum through the range, between Báramúla and Uri, the gneiss does not appear at all; and the slates, in some manner not yet worked out, wrap round the termination of the gneissic mass of the ridge on either side. The abruptness of these breaks has suggested the possibility of their connexion with primitive ridges of old gneiss; but this supposition is so difficult to reconcile with the general symmetry of contortion, that we must seek for some other explanation. Since the main feature is not a simple flexure, but includes also some minor foldings of the strata, as is observed in both the Banihál and Pir Panjál sections, it is natural to suppose that at different points of this range the maximum effect took place along different minor axes of initial contortion, resulting, of course, in ultimate discontinuity, and partial discordance between these elements of the great flexure.

One-sidedness of mountain structure.—It has been already remarked (p. 559) that the structural form of the Pir Panjál and Dhauladhár ranges corresponds with that of the ridges of the adjoining Sub-Himalayan rocks. It may perhaps also be inferred that a similar structure prevails in the Zánskár range, but nothing very like it has been described in the interior mountains, nor yet, which is more noteworthy, at the northern margin of the mountain region; the features of the hills on the borders of the Yárkand plains, so far as we know them, bear no resemblance to those of the Southern Himalayas. This one-sidedness of mountain structure has been observed elsewhere, and has given rise to the opinion already alluded to (note, p. 529), that the source of disturbance was external to the mountain region.[1] This notion, however, is decidedly obscure; almost on a par with the original idea of simple upheaval, so long in favour with Alpine geologists. It seems more natural to look for an explanation of the dominant structural form, in any area of special disturbance, to the resultant condition of resistance at the time of compression. Such a local condition has been intelligibly assigned by Mr. LeConte,[2] in the unsymmetrically lenticular form of the total sedimentary mass, from the alteration and compression of which a mountain range is formed, whereby excessive contortion and over-thrust takes place on the side of the most rapid decrease of thickness of the deposits, which would generally be the landward side. This explanation may be partially the correct one for the case under description, although there would still be some difficulty in connexion with the part that has been assigned to the central gneiss of the Lower Himalayas. But it is evident that this particular condition is only one in the many possible combinations by which the position of least resistance under compression may be determined.

Post-tertiary and recent formations.—It has been already explained (p. 371) how difficult it is to draw a distinct line between tertiary and post-tertiary formations in Peninsular India. Indeed, it is sufficiently evident from general considerations that, unless upon the assumption of a world-wide or half world-wide coincidence of phenomena, there

[1] Suess: Die Entstehung der Alpen. An abstract of this work is given in Silliman's Journal, 1875, p. 446.

[2] American Journal of Science and Arts, August 1878, and elsewhere.

Mr. J. LeConte (and he is not singular in this) seems to have overlooked the fact that a very large and vital a part of his theory is contained in views admirably expounded long ago; it is by no means evident in what particulars, as a "formal theory," the "geanticline" differs from De Beaumont's *bossellement*, or the "mashing" from the *écrasement* of the same author; or how the part played by "sedimentation" in the origin of mountains differs from that assigned to it by Herschel and Babbage. The little progress geologists have made has been in applying the ideas of these physicists to actual cases of mountain-structure.

can be little or no correspondence between the great breaks in the sequence of geological formations in distant parts of the earth's surface; and the chief interest of the case under immediate notice is, that the traces of such a half world-wide event have been observed in the Himalayas. On the page above referred to it was stated that the limit between tertiary and post-tertiary formations in Europe is most conveniently marked by the glacial epoch; and on the following page it was shewn that India had been affected by the glacial period, and that Himalayan glaciers were formerly more extensive than they now are. That evidence need not be quoted again here; we would only draw attention to the fixing of the date and the cause of that former extension, as necessary features of the important question at issue—the validity and force of the words "epoch" and "period," as applied (without local affix) to glacial action; for, as so used now, they imply a half world-wide, if not a world-wide, coincidence of the phenomena; and the importance of verifying this application is very great. Even if one such event could be established, it would be of immense service, in giving a rough general datum line in past time from which to correlate the progress of geological changes; for at present there is no greater obstacle to exact speculation in geology than the utter uncertainty between local and true time, as indicated by the palæontological clock.[1] It will require a great accumulation of connected observations to establish the cotemporaneous glaciation of even a hemisphere of the earth—to shew, for instance, that the facts appealed to are not successive, and due to a progressive change, more or less irregular, such as would be caused by a shifting of the earth's axis, although the possibility of this particular occurrence has lately been denied by competent physicists. In such a case the expression "glacial epoch" would have little more exact significance than have now the various palæontological periods.

Sub-Himalayan high-level gravels.—The evidence for a stratigraphical break in the formations of India, equivalent to the pliocene-pleistocene change in Europe, is not found most distinct in the same localities as the best evidence for an extension of glacial action. The latter naturally occurs in the higher ground, towards the region of existing glaciers; the best instances on record being those in Sikkim (*supra*, p. 373) and Kashmir.[2] The former, as naturally, is found in connexion with the known tertiary deposits in the Sub-Himalayan zone. Nothing could be more sharply defined than the separation of the high-level

[1] *e. g.* Dr. John Evans' objections to Professor Haughton's considerations on Changes of Climate in past times. Presidential Address (Geological Section), British Association, 1878. "Nature," Vol. XVIII, p. 418.

[2] Drew: Jummoo and Kashmir Territories, p. 219.

gravels along the base of the North-Western Himalayas, from all recent deposits on the one hand, and on the other from the latest rocks of the tertiary series—the topmost Siwaliks. In the section already so much quoted of the Sutlej gorge above the Bubhor (p. 551), those gravels are found capping the low hills, at an elevation of 500 to 600 feet over the river, and resting undisturbed on the edges of vertical Siwalik conglomerates. The same may be seen in many other places, as in the river section of the Rotás ridge, west of Jhelum; and it will scarcely be disputed that, from stratigraphical analogy, they may take provisional rank as early pleistocene. In the places indicated they are made up of thoroughly water-worn torrential debris, but in certain positions, as in Kángra, they have a character that seems to demand the aid of glacial conditions; and this only occurs when there is an obvious source of such an influence. The whole Kángra valley and many other dúns were once more or less filled with these deposits. The boulder gravel caps ridges above Kángra fort, on the southern side of the valley; and all about, especially on the inner side of the valley, huge blocks of gneiss are scattered. These blocks are not traceable to distinct moraines; but they often occur in sheltered positions, to the side of the actual gorges, where they must have arrived by flotation, or else have fallen over the present flanking ridges when these were smothered in a great fan-talus of diluvium from the main ridge of the Dhauladhár close by. No scratching or polishing has been found either on the blocks, or on the rocks *in situ*; but all the facts very strongly suggest that glacial conditions must have aided in producing such results. The elevation of this sub-glacial deposit in Kángra is between 2,000 and 3,000 feet; the crest of the Dhauladhár, from 6 to 8 miles distant, rising to 14,000 and 16,000 feet.

Glacial evidence in Tibet.—The effects, real or imputed, of glacial action in the Alps and elsewhere are so prodigious, that, after accepting some clear cases, such as those quoted in Sikkim and Kashmir, of old moraines at elevations of only 6,000 to 8,000 feet, one is surprised to find that traces of glaciation are not more conspicuous elsewhere in the Himalayas at vastly greater elevations, in Tibet. At least, but slight mention is made of those traces by very competent observers. Dr. Stoliczka may be said to have ignored the subject; Colonel Godwin-Austen, who surveyed the highest regions of Western Tibet, and who from the first paid attention to geological features, only makes casual mention of glacial extension, generally in its least certain form—that of presumed erratics; and Mr. Drew, who enjoyed such exceptional opportunities of studying the ground, and who paid particular attention to this subject, as is proved by his admirable account of the superficial deposits of Western

Tibet,[1] makes less distinct mention of glacier extension here than at much lower elevations to the south. He does, indeed, describe deposits of the glacial period, but as being scarcely different from the actual torrential deposits: and to the other marks of glacier-action there is very little allusion. The spurs at the edge of the Deosai plain are said to shew signs of ice-moulding,[2] and a few instances of contorted alluvium are attributed to the presence of glaciers at lower elevations than at present; but Mr. Drew's chief argument, so far as his work has proceeded, for the influence of the glacial period in Tibet is the indirect one—to account for the excess of disintegrating action, whereby the river valleys became choked with diluvial matter. It is even remarked (*l. c.*, p. 470): "Whether in that period there was any variation in the transporting power of the streams, I do not at present see my way to determine; the material is, as a whole, of the size that is even now brought down by the streams, taking the spring and occasional floods into account." What these occasional floods may do has been already stated (p. 516). On the whole, the published descriptions of Tibetan regions are not what might be expected, had the ground been deeply covered by ice, as would surely have been the case at a time when on the southern side glaciers reached so low as 7,000 feet. But these doubts are only conjectural, and intended to elicit further research.

The Hundes lake-basin.—The immense extent of what we may conveniently (until we know more about them) call "post-Himalayan deposits" in Tibet has already been indicated in our remarks on the plain of Hundes (pp. 646-51); where some doubt was hazarded as to whether the remains of the extinct mammalia were really derived from the undisturbed deposits of that high-level basin. If the "glacial epoch" test might be applied here, it would confirm the supposed Siwalik age of these beds; for General Richard Strachey mentions the existence of old moraines upon them.[3] From an observation recorded by Captain Henry Strachey [4] it would seem that they are truly lacustrine: he speaks of the ground by the name "*Guge*," and says that the deposits "appear to consist of more finely comminuted material in their central part, where furthest distant from the mountains, the great ravines there being flanked by cliffs half a mile high, which exhibit throughout their thick-

[1] Drew: "Alluvial and Lacustrine Deposits and Glacial Records of the Upper Indus Basin," Q. J. G. S., 1873, XXIX, p. 441; and "Jummoo and Kashmir Territories," 1875.

The paper in the Quarterly Journal is headed Part I, and only treats in detail of the alluvial deposits; it is understood that the "Glacial Records" were to have been described in the second portion of the paper, which has not yet been published.

[2] Q. J. G. S., XXIX, p. 466.

[3] Q. J. G. S., VII, p. 310.

[4] "Physical Geography of Western Tibet," Jour. Roy. Geogr. Soc., 1853, XXIII, p. 19.

ness a fine homogeneous clay with little gravel in it. The stratification of the alluvium seems to be horizontal in all cases, or at most very slightly sloped from the mountain foot to the valley middle, in accordance with the existing directions of the drainage. I have once or twice seen small faults, where some of the strata had become canted from the horizontal for a few yards; but never anything like a general disturbance of the original position."

It is not known whether this great lake-basin is now a rock-basin, or if it ever was; and, as we shall see, there are other larger and more lofty lake-areas, the origin of which is distinctly attributed to the damming up of the gorge of discharge. The fact that the gorge and the deposits themselves have been re-excavated to so great a depth, is another point in favour of the greater antiquity of the Hundes deposits; and, on the whole, the balance of evidence is in favour of their being of late tertiary (Siwalik) age. It would be a crowning proof of the fact, already sufficiently established (p. 570), that the great Himalayan river-basins existed in Siwalik times, as now. A comparison of the state of these deposits with that of the older tertiary deposits of the Indus valley, is a further suggestion, that the post-Siwalik disturbance was quite a minor, or collateral, effect of that which produced the contortion of the mountains.

Lingzhithang and Kuenlun lake-basin.—The great lake-basin of Lingzhíthang, and the Kuenlun plains,[1] are in a much newer phase of existence than that of Hundes, although of greater extent, and at a higher elevation. They stand at the main Himalayan watershed, north of the Indus; and have apparently been reclaimed from the northern drainage area. They are now in the last stage of extinction as lakes, having numerous small shallow tarns and ponds of salt water still left in the lowest depressions. They occupy an area 100 miles long from north to south, with an average width of 70 miles, divided by the Lokzhung mountains, or what is left of them; for the watershed in the gorges is only 300 feet above the southern plains, and altogether on gravel; while some of the peaks range to 21,000 feet. The Lingzhíthang plain, on the south, has an elevation of more than 17,000 feet, and the Kuenlun plains 16,000. The original outlet is supposed to have been at the north-east corner, into the eastern Kárakásh valley. This became choked by fan-deposits from the lateral gorges; and so the lakes were formed, and ultimately the plains.

Tso Moriri and other basins.—Mr. Drew describes several other similar areas, on a smaller scale; such as the little salt-lake plain of

[1] Drew: "Jummoo and Kashmir Territories," p. 331.

Rupshu, and the saline lakes of Pángkong and Moríri—all attributed to the same mode of formation. The Tso Moríri gives the most distinct illustration of this process; the Phirsa stream brings down to the main valley more debris than it can carry on, and thus has raised a dam across the valley. The greatest depth of the lake is 248 feet; but the fan of the Phirsa apparently has that depth, besides being now, at its lowest point, about 100 feet higher than the lake.

Around all these lakes and lake-plains there is clear evidence that the waters have formerly stood at a much higher level. This fact points to a continuance of the cause which originally gave rise to these lakes—a progressive decrease of precipitation and increase of evaporation, whereby the carrying power of the streams has become more and more out of proportion to the rate of disintegration of the rocks.

Alluvial deposits of Tibet.—This clear evidence of a change that is still in operation is the more noteworthy, as it is apparently the reverse of a process which is appealed to in explanation of a more wide-spread development of other deposits in the valleys of Tibet. Mr. Drew makes a very important distinction between lake-deposits and river-deposits, or alluvium; the principal criterion being the horizontality of the former, their lamination, and the absence of larger, current-borne materials: and he considers that the great accumulations of debris found in almost every valley, high above the present stream level, are river-deposits, not lacustrine; also, that they were deposited since the valleys were eroded to about their present depth; and that, therefore, a double change took place in the relative carrying power of the streams, before and after the formation of those deposits. In this case the changes of balance are accounted for by the abnormally increased disintegrating action from the cold of the glacial period; to which time these beds are thus relegated. This is, in fact, the principal evidence referred to for the glacial epoch in Tibet. The general description of the nature of these deposits is quoted above (p. 670); and it is hardly what one would have expected from the supposed conditions. May not these old valley deposits be in part the result of temporary lakes, such as may at some time or other have been formed by obstructions at different points of the deep valleys; and in part, deposits of the time when the valleys first stood at those levels? The Indus is now laying out alluvial plains at several points of its valley in Ladák.

The Kashmir basin.—None of the Tibetan lake-basins, actual or extinct, are known, or supposed, to be rock-basins. Indeed, they are plateaus as much as basins, on account of their elevation, and because the height and width of the lip separating them from ground at a much

lower level are inconsiderable. This is remarkably the case with the Ling-zhíthang basin. The Kashmir valley is much more basin-shaped. Its length is about 84 miles, and in width it varies from 20 to 25 miles; the lowest elevation is 5,200 feet, the mean for the whole valley being about 6,000 feet, or 5,000 feet above the plains of the Punjab, from which it is separated by the Pir Panjál range, the lowest pass in which is 3,000 feet over the valley. Kashmir is still in part a lake-basin, and a much larger part is occupied by very low alluvial land, formed by the overflow of the actual rivers; the rest is occupied by flat terraces and plateaus, from 100 to 300 feet above the alluvial surface, and known by the vernacular name *karewas*. Both surfaces rise as they come within the influence of torrents and rainwash from the surrounding hills; in this way the karewa surface rises to an elevation of 7,000 feet.

Colonel Godwin-Austen[1] observed that at the outer edge of the valley, especially on the south-east, the karewa deposits have an inward dip of more than 20°; and he estimated their thickness at 1,400 feet. Throughout this thickness the remains of recent, land and fresh-water, shells were repeatedly found, also plants and fish scales; peaty layers also occur at several horizons, indicating a succession of land surfaces, alternating with the lacustrine deposits. Mr. Drew[2] confirms the opinion, that the karewa deposits are lacustrine and not alluvial; but he seems (*l. c.*, p. 212) to suggest a distinction between these disturbed beds and the material of the karewas proper. Mr. Lydekker,[3] however, describes a perfectly gradual transition from the disturbed blue clays and conglomerates on the outer side of the valley, up into the horizontal pale fine sands and loamy clays forming the plateaus in the centre and on the inner (north-east) side; but he suggests the convenient distinction of upper and lower karewa deposits, and considers that the former may be of upper Siwalik age.

It seems most likely that these deposits now lie in a rock-basin, the tilting of the lower strata probably corresponding with a late relative rise on the side of the Pir Panjál. Colonel Godwin-Austen and Mr. Drew, however, only refer to possible obstructions in the Jhelum valley in connexion with the old lake; although the latter observer (*l. c.*, p. 211) contemplates its having risen to a level of 7,000 feet above the sea, that of the highest karewa slopes, or to 1,800 feet above the present lowest level of the valley. The possible source of doubt in this estimate lies in the uncertain distinction between true deposits in water and the results of

[1] Q. J. G. S., XX, p. 383.

[2] "Jummoo and Kashmir Territories," pp. 161 to 212.

[3] Rec. G. S. I., XI, p. 32.

rainwash. Mr. Drew decides that the ancient buildings in Kashmir are subsequent to any but the recent deposits of the valley; and no relics of man have been found in any beds older than recent. No undoubted marks of glacial action have been observed in Kashmir lower than 500 feet above the valley; the evidence of such action at a lower level is so far confined to quasi-erratics in or about the gorge of the Jhelum.

The Nepal valley.—The only other valley at all comparable with that of Kashmir is Nepál,[1] in the Lower Himalayan area. The superficial differences correspond with those that mark the structural characters of the two regions; both are longitudinal valleys, lying in the general strike of the strata; but the clear open oval area of Kashmir approximately coincides with the elliptical synclinal depression of the calcareous upper palæozoic strata, a form that is so generally marked wherever the Himalayan disturbance has been unobstructed. Nepál, on the contrary, is rather a group of confluent valleys, with high dividing spurs: in both directions, on the prolongation of the strike of the rocks, there is a continuation of the special excavation of the mountain zone; and the rocks of this zone being prevailingly calcareous, has suggested the conjecture (*l. c.*, p. 92) that the feature is primarily due to erosion by solution; as may also be the case with Kashmir. Another cause, however, and the proximate one (*l. c.*, p. 100), of the formation of a lake-basin in Nepál, was probably, in part, a relative rise of the hills on the south; for here, too, the bottom beds of the valley deposits have undergone local disturbance on this side.

These deposits correspond very closely with those of Kashmir. There is no remnant of a lake; but the other features are alike. An extensive upland area, known as *tánr* land, corresponds to the karewa of Kashmir, and to the bhángar of the Gangetic plains. It is the surface of the old lake-deposits, no doubt considerably modified by waste in the central parts, and by rainwash accumulations near the hills. The streams flow at a depth of from 50 to 500 feet below this surface, according to position; but here too, as in Kashmir, they are now, for the most part, subject to overflow, and thus form the alluvial valleys, known as *kholas*, the khádir land of the plains (p. 403). Beds of serviceable peat, much used for brick and lime burning, occur at various levels in the valley deposits; and there is also a blue clay, extensively used for top-dressing the fields, and the fertilising virtue of which seems to be due to the phosphate of iron (vivianite) freely scattered through it in blue specks. No fossil remains have, as yet, been found in any of these deposits. Any

[1] Rec. G S. I., VIII, p. 93.

trace of glacial action is also wanting in Nepál; not even the doubtful erratics occur. But such could only be expected on the assumption of very advanced glacial conditions; for Kathmándu is only 4,509 feet high, and the valley is not traversed by any river from the snowy range, but forms the head-waters of the Bághmati; the highest summit of the surrounding ridges being Phulchok, on the south of the valley, with an elevation of 9,720 feet.

Other lakes.—There are a few insignificant lakes near the outer fringe of the mountains, which may be accounted for in the same way, or by obstruction caused by landslips. A cluster of such ponds lies about Naini Tál[1]; and some occur also in the Sub-Himalayan zone, as at Kundlu, on the road from Rupár to Beláspur. Mr. Mallet describes[2] some tiny lakes at the edge of the tertiary zone in Sikkim, as formed by landslips. In one, the stumps of the trees that were growing on the sides of the valley at the time, are still standing.

It is apparent how very different are the lakes, actual or extinct, of the Himalayas from those of the Alps; the distribution of lacustrine rock-basins in the latter ground being as markedly marginal and transverse, as in the former it is internal and longitudinal. Yet it is quite possible that both may be principally due to a like cause—changes of level in the mountain mass, due to lateral pressure, which would take effect variously, according to the form and dimensions of the ground affected.[3]

Drainage lines.—In connexion with the alluvial and related deposits, a few suggestions may be made regarding the drainage. Rivers are one of the most palpable, most widespread and ceaseless agents of geological changes; and dwellers in India have before them unsurpassed examples of the magnitude of their operations, both for construction and destruction. Yet we have hardly outlived the time when much of this river-action was ignored. Until recently, the deposits forming the great Indo-Gangetic plains were regarded as of marine origin. The positive, constructive action of rivers is now better understood, as it is, of course, more open to observation and verification; and use has been made of it above (p. 570) to shew the antiquity of the rivers and of the mountains (or at least of the land-surface) from which they flow. The negative or destructive operations are much less susceptible of direct proof; and accordingly there are still some who believe that the great gorges and valleys of the mountains are the gaping fissures of the fractured earth. In detail it is perfectly easy to confute this supposition;

[1] Ball: Rec. G. S. I., XI, p. 174.
[2] Mem. G. S. I., XI, p 7.
[3] Q. J. G. S., XXIV, p. 51.

to shew in countless instances that the rocks in the deep gorges of the river-beds are not, and never have been, so fractured; and once the door is closed against this vein of semi-occult hypothesis, a rational interpretation of the forms of denudation, based upon known and measurable modes of action, becomes possible, and a new record is opened to the geologist.

The conditions of this mode of action have never been very systematically formulated, although few natural processes have to work with so simple and axiomatic a rule—that water will not rest unsupported upon a slope, and must flow by the lowest channel of escape. The uncertainties of the problem arise from unknown partial interferences, by ground movements, with the original levels; but of these influences also, evidence should be forthcoming, as is that of the changes which occur normally in any large drainage system, whereby an originally transverse[1] drainage may become by itself more or less converted into main longitudinal channels.

This normal process of formation of river-systems is too well understood to need explanation here[2]; and it is evident that abnormal changes of the drainage lines, by local disturbances of the ground-levels, should also be traceable; though it might not always be easy to assign the exact cause: for example, a small additional tilt of the outer range would have sent the drainage of the old Nepál lake down the longitudinal valley to the south-east; but the gorge of the Bághmati would have remained as a permanent testimony of a former state of things.

We may now indicate the application of these considerations to some features of the Himalayas. The case of the Chináb has been already noticed (p. 562), where it passes by a deep narrow gorge at Riássi through a lofty ridge of palæozoic limestone, surrounded by much softer tertiary rocks, the ground to the north being several thousand feet lower than the crest of the ridge. That gorge not being a fissure—it is tortuous, and the rocks are perfectly continuous and unbroken across the river-bed at both ends—it must have been slowly excavated by the river; and throughout that process the ground to the north must have been higher than the river in the gorge, and so originally higher than the present crest of the ridge. It cannot be asserted that the surface to the north of the ridge was ever higher than it is now; for the disintegration of the tertiary rocks and the erosion of the gorge may have kept pace with the gradual

[1] See note, p. 529.

[2] For an admirable illustration of the process referred to in the text, see a paper by Mr. Jukes, "On the mode of Formation of some of the River Valleys in the south of Ireland," Q. J. G. S., XVIII, p. 378, 1862.

elevation of the whole ground; while the resistance of the older rocks preserved them to be elevated to their present position. Or, the ridge being distinctly a case of locally greater upheaval, the erosion of the gorge, on the primitive course of the river, must have kept pace with that special elevation; for otherwise the stream would have made a new channel through the softer rocks. But the fact remains absolute, that within the lifetime of this river, the rocks forming the crest of this ridge must have been lower than the ground to the north.

More important, though less striking, are the cases to be found in the higher mountains. That all the great Himalayan rivers have their sources well to the north of the line of greatest elevation in the main snowy range, has for long been a familiar fact; and also that the three largest of them—the Indus, the Sutlej, and the Sangpo or Brahmaputra—run for great distances in longitudinal courses within the mountains, so as almost to draw their head-waters from a common source in a middle position. We have no direct observations upon the gorges of these rivers in the high mountains, as to whether they can be regarded as lines of fissure; but all the collateral evidence is decidedly against that assumption. We may at least glance at the question as if these river-courses had been selected under the simple conditions that govern formation by erosion.

We cannot here assert positively, as in the case of the Riássi gorge, that the river valleys through the snowy range were originally filled by a mass of rock, continuous with the mountain crest on either side; although the probability is that they were very approximately so; and it is quite certain that prodigious erosion has taken place in those positions through the agency of the rivers. It can then be absolutely asserted (*if we ignore the supposition of original fissures*) that throughout that process of erosion, and at its origin, the whole ground to the north was higher than these transverse drainage lines, through what is now the main mountain range; and, therefore, that this range (as such), at present the most conspicuous feature of the mountains, is of later date than these river channels.

The facts further point to the probability that the present longitudinal character of the Himalayan drainage may have been more or less brought about from an original transverse type, by the normal process of change alluded to in a previous paragraph. The gorges of the greater torrents, the Sutlej and the Indus, are much deeper than those of the other rivers draining through the main range; and they may thus in process of time have intercepted and drawn off the original head-waters of the latter streams, which may have originally drained from beyond the basin of the sedimentary rocks. No doubt the story may have been otherwise, and these longitudinal rivers may have been more or less

aboriginal, through circumstances that are easily imagined; but the question is not beyond the range of evidence; and the fact that the minor rivers have been able to open, or keep open, a passage through what is now a great mountain barrier, is suggestive that for a considerable period they had a larger source of power than now.

These considerations upon the drainage system lend some support to views upon the mountain structure derivable from the rocks. It has been suggested, with some probability, that the great sedimentary series of the Central Himalayas was originally laid down in a continuous basin of deposition, though now broken up into great synclinal basins of disturbance, represented on the north-west by the Zánskár and the Kárákoram areas; also, that the "central gneiss" of the "main range" and the Lower Himalayas has always been an elevated mass relatively to that basin of deposition. Upon these seemingly probable inferences (or assumptions) the gneissic axis of Ladák now dividing these basins of disturbance, and formed in whole or in great part of metamorphic palæozoic rocks, must be considered as the chief and central feature of Himalayan disturbance, and the line upon which the greatest amount of upheaval occurred, whatever elevation it may at any time have attained. The drainage system, at least in the middle region of the mountains (Hundes), strongly suggests that it originated from that central axis of disturbance as a line of relatively greatest elevation; the fact that the drainage took its origin from a watershed somewhere to the north of the present main chain being a certainty.

Two views are compatible with the facts: either the elevation of the whole area was equable, and the original spill from that central crest of upheaval, across what is now the position of greatest elevation, has been maintained simply by erosion, the present less elevation of the central range (Ladák axis) being also a result of denudation, as may well be the case; or, there has been a subsequent special elevation along this line of the present main Himalayan range. In this case, this special upheaval must have been so gradual that the erosion of the passes could keep pace with it; or else these had been for the most part cut down before it set in. The latter supposition, of a partial later elevation of the Himalayan range proper, would help to account for the great lake of Hundes; although the basin itself, as formed by the drainage of the Sutlej, is probably of older date. In the case of the limestone ridge at Riássi, we could shew that such a special marginal upheaval had taken place; for that limestone at no very distant period had formed part of the level bed of the nummulitic sea, and so, at the commencement of the disturbance, must have stood at a lower level than the upper tertiary rocks to the

north of it. The case is different for the gneissic axis of the main range: we have seen reason to think that from very early times it has formed a relatively elevated mass; but we have also (p. 604) shewn reason to suggest that this fact may have led to its special elevation under certain conditions of disturbance by compression.

Summary.—Beyond the fact that a very full sequence of formations has been palæontologically established in the Tibetan regions, there is little to bring forward from this chapter as general results.[1]

(*a*). The relation of the lowest strata of the slate series on the Tibetan side, to the gneiss of the main chain and of the Lower Himalayan area (p. 628), indicates their wide separation in age, and, so far, agrees with the more marked stratigraphical break between that same gneiss and the slate series to the south of it, in the Lower Himalayan area (p. 620); so far confirming the probable equivalence of the two slate series, and establishing this gneiss as a primitive rock in the Himalayan series, forming here a sort of neutral block in the disturbances that have produced the mountains. It might thus, too, be regarded as having formed here a primitive Himalayan range, from which the quasi-erratics of the Pángi slates were derived (p. 664); and Dr. Waagen in the paper just quoted (see note) makes use of it in this way to account for the contrasting life-conditions of the areas north and south of it, throughout the palæozoic and mesozoic epochs, thus connecting it with the Peninsular rather than with the true Himalayan region. However this may have been in pre-Himalayan times, considerations upon the drainage system have suggested (p. 676) that since eocene, or, at earliest, cretaceous times, it has not always been, as now, the principal crest of Himalayan elevation.

(*b*). The few instances of thinning out of deposits that occur in the mesozoic formations (p. 643), again indicate this Lower Himalayan area as a southern limit of deposition; although in several of the groups there is no symptom of any such limitation (p. 642).

(*c*). The extensive metamorphism of the palæozoic rocks in other positions, especially on the central axis in Ladák, may suggest the opposite condition in those positions—that a greater depression and accumulation of deposits had occurred there; unless that metamorphic state is to be accounted for by the greater compression and upheaval of which those positions have been the *loci*.

[1] For a partial comparative discussion of the palæontological data, we may refer our readers to an essay by Dr. Waagen in the Denkschriften d. Math.-Naturwissenchaftlichen Classe d. K. Ak. d. Wissenschaften. Wien., Vol. XXXVIII, 1878; and Rec. G. S. I. XI, Pt. 4, 1878. This general subject is also treated of in the Introduction.

(*d*). In the central, as in the outer Himalayas, the relations of the tertiary rocks are of chief importance in the history of the mountains; and already some interesting points have been made out. From the Sub-Himalayan sections it was shewn (p. 569) that an eocene land had existed in the Himalayan area. The distribution of the nummulitic deposits in Tibet, so far as accurately known, would independently suggest the same fact: they are totally cut off from connexion with all preceding deposits, and now lie in a compressed trough, chiefly in contact with the metamorphic palæozoic strata, in the very centre of Himalayan disturbance, where presumably the maximum of total upheaval took place (p. 678), *i. e.*, including pre-tertiary with post-tertiary elevations. After the cretaceous epoch, a prolonged elevation set in, involving the corresponding denudation of the whole sedimentary series down to the altered palæozoics, and the rise, on adjoining areas, of mountains having a height at least equalling the thickness of the mesozoic series; this position of maximum upheaval, on the Ladák axis, corresponding with that of greatest denudation, where subsequently the eocene deposits were accumulated. It is, of course, clear that at the beginning of the tertiaries, these depressions of the Himalayan area were still, or again at the sea-level. This preliminary, pre-tertiary stage of Himalayan elevation, of the whole area we now speak of as Himalayan, would very closely correspond with the period of the Deccan trap of the Peninsula.

(*e*). It is a point of very great interest to ascertain how far, if at all, that pre-tertiary elevation of the Himalayan axis was accompanied by the disturbance of contortion which is the special character of the Himalayan mountains (p. 634). No fact is better established in the Sub-Himalayan zone, at two distinct points (p. 569), than that the special disturbance of the silurian slates there is altogether post-eocene, subsequent to the elevation of the central area, as just described. Can it have been so also in the central region? If so, the history of the mountains would be brought within a narrow compass: a broad, unbroken, pre-tertiary elevation of the area (clause *d*), followed in middle tertiary times by a break-up and compression into flexures. If not, if the plication also of the central region preceded the deposition of the Indus tertiaries, a pretertiary act of special Himalayan disturbance would be marked off, distinct from that which produced such great effects on the southern border of the mountains. It is certain that extensive crushing and folding of the central region, with irruption, took place after the Indus tertiaries; but there is no observation as to whether in degree, or by discordance, it can be distinguished from an earlier contortion; and thus it

is still an open question whether the special Himalayan disturbance is altogether post-eocene.

(*f*). There remains the important question, how far the rising of the mountains to their present elevation coincided with the act, or acts, of plication (*écrasement*, "mashing;" *see* note, p. 667)? It is quite clear that the special Himalayan contortion had been practically completed, and the mountains had very approximately assumed their present sculpture, when the undisturbed strata of the Hundes basin were deposited (pp. 651-670). If those deposits are Siwalik, it would be plain that the very considerable contortion of the latest Siwaliks of the Sub-Himalayan zone took place, as has been suggested from other facts (p. 570), long after the principal contortion of the mountains, as a whole, and after they had approximately assumed their present contours. There remains, however, the very important question of elevation, as distinguished from form and structure: it is strongly objected, that the rhinoceros could not have lived at the present elevation of the Hundes deposits. When the possibilities of this condition are fixed, we may be able to record another, and perhaps the latest, event in the physical history of the mountains—a great continental elevation of the area, without sensible contortion of the rocks, and after the sculpturing of the mountains to very nearly their present shape had been accomplished. Any clear evidence of simple and extensive upheaval, distinct from, and long subsequent to, the chief special plication so characteristic of the mountain region, would be an interesting contribution to the theory of mountain-formation.

CHAPTER XXVIII.

EXTRA-PENINSULAR AREA.

THE ASSAM RANGE.

Area to be described — Formations present — General structure — The Sylhet trap — The cretaceous series: Khási area — Gáro area — Mikir area — The nummulitic series: Khási area — Gáro area — Eastern extension of the nummulities — The upper tertiaries — The Nága coal-fields.

Area to be described.—The ground to be described in this chapter is a kind of residual area, for which even a name has to be invented. Assam, as known in geography and in the Anglo-Indian vernacular, is the valley of the Brahmaputra, from the Brahmakhund to Dhubri, a direct distance of 420 miles; and this has been already described in the chapter on post-tertiary deposits (p. 405). The northern border of the valley has also been described in the Himalayan chapters (pp. 545, 618). There remain the hills bounding the valley continuously on the south, and now included in the province of Assam, recently formed into a local government, under a Chief Commissioner. The close connection between the hill tracts and the Assam valley justifies us in speaking of these hills collectively as the Assam Range, in order to use one general term instead of the five or six names now applied to different portions of the hill country, as was explained on page 27. This confusion of names is, however, to a great extent founded on the undecided or contrasting features of the ground, as may be apprehended from the statement that more than half of this range has already been described as structurally belonging to the peninsular area.[1]

The hills formed of these most ancient rocks, and occupied by the Gáro, Khási, Jaintiá, and Mikir tribes, are for the most part low and very irregular on the north side, with numerous outliers in the Lower Assam valley, even close up to the Himalayan border (p. 522). On

[1] For the little we know regarding the gneiss forming the great mass of the hills, extending for 250 miles, between the Dhansiri and the Lower Brahmaputra, we must refer the reader to page 26; and the transition rocks associated with the metamorphics are noticed at page 40.

the south and south-east the metamorphics are everywhere overlapped by very much newer strata, upper secondary and tertiary, which in this position are still undisturbed; and so form plateaus between the deep river gorges, with a high scarped face along a regular line to the south. To the south of this line, the same neozoic strata are greatly disturbed; and consequently form hills of very different outline from that of the adjoining table-lands. This remarkable feature is badly seen in the middle region, that of the Khási and Jaintiá hills, where the alluvial plains of Sylhet reach nearly to the base of the plateau, with only a very narrow intervening outcrop of the disturbed rocks. To the west, in the Gáro country, the fringing zone of low hills is somewhat broader, between the plains in Mymensingh and the crystalline rocks of the Tura ridge. To the east of Jaintiá a complete change takes place rapidly in the relative magnitudes of these contrasting features; the dividing line curves gradually to the north-east, so as to emerge in the Upper Assam valley, near Golághát, on the Dhansiri; while the formations in the zone of disturbance expand enormously in the Nága country, and rise into a range of hills that quite overlooks the crystalline area. In North Cachar this is known as the Barail range, and its prolongation to the north-east, separating Upper Assam from Manipur and Burma, is called the Pátkai range. It is confluent with, and a member of, the Indo-Burmese mountain-system, of which the Barail-Pátkai range may be considered a border zone, near the original margin of the deposits which principally constitute that region of special disturbance.

It is thus plain that the Assam Range is made up of two very distinct portions. Besides its strong petrological resemblance, the characters sustained by the gneissic mass, as an area at least partially, reserved from deposition, and as a neutral block of ground, unaffected by the disturbances that have operated so powerfully in adjoining areas, mark it clearly for affiliation to Peninsular India. For these reasons it has been described in that connexion, and distinguished from the adjoining hills under the title of the Shillong plateau.[1] Thus only the newer formations of the range remain to be noticed. The description must be given in the same disjointed manner as for the Himalayan area, because our information[2] is equally fragmentary in the present case.

1 Mem. G. S. I., IV, p. (427).

2 The following papers refer to the ground under description :—

Oldham : Mem. G. S. I., I, p. 99.

Medlicott : Mem. G. S. I., IV, p. (387); VII, p. (151); Rec. G. S. I., VII, p. 58.

Mallet : Mem. G. S. I., XII, Pt. 2.

Godwin-Austen : J. A. S. B., XXXVIII, 1869, Pt. II, p. 1.

Formations present.—The rocks to be described have only been studied with any care in two positions, far apart: one, on the Khási hill section, at Cherra Poonjee, and one in the coal-fields of the Nága hills, in Upper Assam; and although the formations in both are, presumably, on the same general horizon, the petrological differences are so great, that no exact correlation of groups can be attempted. In the former ground the rocks are seen resting upon, and immediately contiguous with, the gneiss, and some very noteworthy variations of composition in the several groups have been observed in this position. The gneiss does not appear near the Nága hill coal-fields, although it may underlie the upper Assam valley at no great distance. The descriptions of these two areas will be given separately; and it is only possible to give the most general designation of the formations as applicable to the whole area, in the following form:

> TERTIARY SERIES.—An immense thickness of soft sandstones and clays, based upon a nummulitic group, in which limestone is locally in force; coal also occurs.
>
> CRETACEOUS SERIES.—Sandstones and shales, with local coal basins.
>
> JURASSIC (?)—The Sylhet trap, stratified.

General structure.—The leading characters to be exhibited in these formations are—the original termination, either abrupt or gradual, of each against, or upon, the old rocks of the Shillong plateau, clearly marking this as the margin of a great basin of deposition; and, the subsequent disturbance of the whole sedimentary series up to the edge of the crystalline mass, shewing that the latter has been comparatively unaffected by the forces that produced so much contortion in the adjoining ground. It is further of interest to observe that there is a great decrease in the thickness of the sedimentary series from east to west—a fact supporting the conjecture of the original continuity of the gneissic area with that of the Peninsula. It is also of special interest to find a corresponding steady increase of disturbance from west to east, confirming the well-founded opinion of a direct causal relation between the original and induced structural conditions—between the amount of deposition and the degree of disturbance.

In one respect there is a noteworthy discrepancy between the relation of the gneissic mass and the newer stratified series, in the Assam Range and in the Peninsula. In the latter the fringing marine deposits everywhere flatly overlap a very irregular surface of the gneiss: a similar relation is found where the strata rest upon the metamorphics of the Shillong plateau; but in this Shillong ground there is a marked outer line of southern limitation of the older rocks, at many points of which line the

newer strata abut against the older, as mentioned above. It can be seen on the general map, and better still on the small hill-ranges map in the Introduction, that this feature would seem to belong to the Himalayan system, being remarkably parallel to the Eastern Himalayan border in Assam; or even as if it might once have formed a continuation of the middle Himalayan boundary. Such a temporary connexion cannot, of course, annul the more fundamental connexion of the crystalline rocks with those of the Peninsula; but, whatever this seeming Himalayan connexion may mean, it will be shewn that the feature in question is not due to the middle tertiary disturbance, by which the Southern Himalayan border was defined (p. 570), or to the post-tertiary disturbance, of which the Barail-Pátkai range is an effect: although the exposure of the feature is, of course, owing to the disturbance and removal of the covering rocks, it will be shewn that this steep face of old rocks is older than the Sylhet trap, and that it gave its form to the feature of disturbance, instead of the reverse.

This distinctly local cause for a feature of direction having such magnitude as the Barail-Pátkai range, more than 400 miles long (measured to the Brahmaputra), removes, or at least greatly reduces, any difficulty that might have been preconceived regarding this range belonging to the Indo-Burmese, rather than to the Himalayan, system of mountains; although for a considerable distance the two run directly at right angles to each other. The Barail, with its structural continuation westward to the Brahmaputra, may not be strictly a monogenetic component of the meridional ranges of the adjoining area to the south; but all the accessories of disturbance are common to both, as formed of immediately continuous formations in the same basin of deposition. The monoclinal flexure along the edge of the Shillong plateau may have been due to the initial act of depression which culminated in the great waves of compression of the Burmese mountains. These explanations are needed to remove the *primâ facie* impression of the necessary distinctness of the Assam, or at least the Barail-Pátkai range, from those to the south, and its equally apparent relation to the Himalayas: though, indeed, this distinction does not imply much difference; both systems of disturbance are so closely related in age, the Burmese being, perhaps, somewhat the more recent. The Shillong plateau portion of the Assam chain stands equally aloof from both areas of disturbance.

With reference to the parallelism of the Barail-Pátkai and the Himalayan ranges, we may also note the contrasting structural features: in the Sub-Himalayan zone of Assam, as elsewhere, the dominant dip of the rocks is inwards, towards the older rocks of the mountains; whereas the

corresponding tertiary formations of the Barail-Pátkai range, where fully developed, dip as constantly southwards, away from the gneissic mass of the Shillong plateau, and towards the southern basin of disturbance.

The Sylhet trap.—The name of the adjoining district in the plains to the southward has been given to this formation, because of its connexion with the area south of the metamorphic mass of the Shillong plateau. All the other formations to some extent overlap the edge of the crystalline area; but the trap ends abruptly against a steep face of the gneiss. These features are beautifully exposed on the paths and in the deep gorges south of Cherra Poonjee. The inner boundary of the trap is so straight and steep, as seen crossing the separate gorges, that the probability of a faulted junction is at once suggested. It is, however, immediately apparent that any such dislocation must be of very ancient standing; for the cretaceous sandstone passes over the trap in an unbroken semi-arch, being horizontal on the plateau and nearly vertical at the base of the hills. The mode of exposure of the eruptive formation is thus in more or less detached areas in the several river gorges, forming together an inner zone, close under the scarp of the plateau. The width of this band in the Tharia river below Cherra is less than two miles; and the height above the sea at which the trap occurs along the inner boundary with the gneiss varies between 2,000 and 3,000 feet, which may be taken as the minimum local thickness of the formation; for the rivers here are very little above the Sylhet plain, which is nearly at the sea-level.

This trappean formation belongs altogether to the basaltic family, and has a strong likeness to the corresponding rocks of the Rájmahál hills and of the Deccan, already described. Close study might reveal distinctive characters; but there has been neither time nor opportunity for this work of detail. The stratified condition is very well seen; and earthy, ashy beds prevail; but there are many flows of hard basaltic rock, both compact and granular, sometimes with much olivine. No dykes were observed in the trap, except at the junction with the gneiss, a boundary which would thus seem to have been to some extent a line of eruption. At the head of the Lián glen (south-south-east of Cherra), some dykes and veins, with transverse prismatic structure, traverse the bedded trap, and penetrate the crystallines for a short distance. The same may be seen in the Bogapáni. It is, however, plain that the junction with the gneiss is one of original contact: this is well seen below Mámlu, south by west of Cherra, where some 200 feet of the topmost earthy trap beds rest on the metamorphic quartzite forming a short spur at Tárna, close to the general boundary.

As no sedimentary intertrappean beds, with or without fossils, have been discovered in this eruptive formation, we can only guess at its age from its relation to the contiguous rocks. Thus it is evidently much older than cretaceous; for it seems to have undergone both disturbance and denudation before the deposits of that period were laid down upon it. This is well seen in the Tharia river, where the trap-flows have a moderate northerly inclination, and are thus transversely bevelled by the cretaceous sandstone, sloping rapidly to the south. No rock is seen below the trap, except the gneiss; so there is a very wide range for conjecture as to its age. It probably corresponds approximately with the jurassic trap of the Rájmahál hills, 200 miles to the west. In any other direction its nearest known petrological congeners would be the sub-recent volcanic rocks of Burma.

The Sylhet trap has not been observed east of the Tharia river, and no doubt it soon becomes concealed in that direction. It is finely seen in the Jádukáta, the Umblai or Kanchiang of the hill people, 40 miles to the west of Tharia, and under very similar circumstances; but it is not again exposed in the Gáro hills. It would seem as if some greater elevation in the middle region, that of the Khási hills, to which the trap is limited, had brought up this lowest formation of the extra-gneissic area in this position.

The cretaceous series: Khasi area.—It is difficult to give an abridged account of deposits where they are subject to much change, and for particulars of these features we must refer to the original descriptions.[1] In the Tharia river, where the strata have a very high southerly dip, there are about 1,500 feet of cretaceous beds between the Sylhet trap and the nummulitic limestone. The bottom 200 feet, next the trap, are of massive, coarse, felspathic and ochrey sandstone. The only beds seen above this here are dark and pale grey shales, locally nodular, calcareous and ferruginous, with some layers of flaky earthy limestone, and of fine, hard, earthy sandstone. There is a similar section on the Bogapáni, 9 miles to the west, with 43 feet of fine sandstone immediately underlying the nummulitic limestone, and probably representing the Cherra sandstone of the plateau. On the Jádukáta, 20 miles farther west, only the bottom sandstone is seen, but in greater force. Near the base of it here some *Brachiopoda*, *Echinodermata*, and fragments of large *Inocerami* were found, and with these marine fossils numerous pieces of fossil resin, the same as occurs so constantly in the coal of this formation. This is the most westerly point at which marine (or indeed any) fossils have been observed in these deposits.

[1] Mem. G. S. I., I, p. 99, and VII, p (168).

In ascending to the plateau, a very marked change is observed in the character of the rocks; the sandy element prevailing here as markedly as the earthy one did in the lower section to the south. About Mahádeo, on the first ledge above Tharia, a glauconitic sandstone is prominent; probably an expansion of the bottom sandstone already noticed. It is traceable at the same horizon at many points in the cliffs south of Cherra. Marine fossils are locally abundant in it. Above this a fine pale sandstone, frequently with broken fragments of plants and also marine fossils, is a characteristic rock; it is often locally calcareous in a very capricious manner. This band is well seen in the Lángpar spur, above the Mahádeo ledge. Above this is the Cherra sandstone, a coarsish hard rock, about 200 feet thick, which forms the edge of the main scarp, and the broad ledges of bare rocks at the edge of the plateau, under the nummulitic limestone. No fossils have been found in it, but it passes down locally into the lower beds, though often sharply separated from them.

In a small collection of fossils from these rocks, Dr. Stoliczka recognised the following species. The highest fossiliferous band, about 200 feet below the edge of the cliff at Mausmai, a coarse sandy limestone, contains small *Lamellibranchiata*, a *Cellepora*, and echinoderms; a finer rock is principally made up of an *Astrocœnia*, allied to *A. decaphylla*.

From about the middle of the series, above Mahádeo, in a stream under Laisophlang, in a soft, ochreous, glauconitic sandstone these fossils were found:—

Nautilus (*? N. elegans*).
Nautilus, with a central siphon; fragments.
Ammonites planulatus.
Am. dispar.
Am. orbignyanus.
Am. ? pacificus.
Anisoceras indicum.
Anis. sub-compressum.
Baculites, near *B. vagina.*
Alaria papilionacea.
Rostellaria palliata.
Gosavia indica.
Cerithium inauguratum.
Tritonidea requieniana.
Hemifusus cinctus.
Phasianella.
Turritella.
Euspira.
Dentalium.
Janira, near *J. fleuriausiana.*
Exogyra matheroniana.
Spondylus striatus.
Modiola typica.
Cardita orbicularis.
Cardium.
Terebratula, near *T. carnea.*
Hemiaster.
Holaster.
Brissus.
Turbinolia.

The facies of this group rather resembles that of the Utatúr beds of Southern India.

From the well-known fossil locality about 2 miles from Tharia, on the fourth cross-cut taken by the foot-path between the zigzags

of the road, or the first below the Devil's Bridge, the following were named:—

Nautilus lævigatus.
Baculites vagina.
Cypræa globulina.
C. pilulosa.
Rostellaria palliata.
Alaria tegulata.
Alaria glandina.
Lyria crassicostata.
Volutilithes septemcostata.
Tritonidea requieniana.
Latirus reussianus.
Pseudoliva subcostata.
Turritella pondicherriensis.
T. multistriata.
Mitreola citharina.
Euspira lirata.
Gyrodes pansus.
Gibbula granulosa.
Nerita divaricata.
Euptycha larvata.
Actæon curculio.
Pecten septemplicatus.
Janira quadricostata.
Gryphæa vesicularis.
Spondylus striatus.
Pecten, near *P. rugosus.*
Inoceramus.
Rhynconella compressa.
Terebratula, sp., probably *T. biplicata* and *T. carnea.*
Ananchytes } several species, but distinct
Brissus } from any described.

Nearly all the fossils of this list occur also in the Arialúr group of Southern India, but there are a number of species in the Tharia beds which appear to be peculiar, and most of them new. It may be worth recording that the observer who collected these fossils considered the latter locality to be lower in the series than the former, which would be remarkable, if true, seeing that the Arialúr group is newer than the Utatúr.[1]

On the plateau at Cherra Poonjee, which is only 6 miles from Tharia, the thickness of the cretaceous series is reduced to 600 feet, and ten miles farther north, about Surarim, there is only about 100 feet, and thus it gradually disappears altogether. Its last remnants do not occur on the highest ground; but in depressions, and along the edges of the gorges, which had also been valleys in the cretaceous time, where the softer metamorphic rocks had been eroded, the adjoining higher ground being generally formed of the Shillong quartzite (p. 40). In this way outliers occur for some distance to the north, to near Moflong, 13 miles due north of Cherra.

It is in these little primitive basins on the plateau that the cretaceous coal is found. The station of Shillong was for years supplied from a tiny coal-basin at Maubilarkar, between Surarim and Moflong. The mineral itself has a persistent character throughout the whole cretaceous area: it is remarkable as being less of a true coal than is that of the overlying nummulitic group; the texture is compact and

[1] See Chapter XII.

splintery, with smooth conchoidal fracture, and the coal gives a dull woody sound when struck; it has the additional peculiarity of containing numerous specks and small nests of fossil resin. The abundance of pyrites is a serious defect in it as fuel.

The top member of the series, the Cherra sandstone, seems to be continuous throughout: it was recognised at the foot of the hills on the Bogapáni, and it covers the coal at Maubilarkar. There is more doubt as to the continuous identity of the bottom group. In the lower ground it is separated from the Cherra band by 1,000 feet of earthy strata, while to the north it seems to coalesce with the Cherra band. This statement implies that there is an apparently continuous bottom band throughout: in the low ground, next the Sylhet trap, the coarse bottom sandstone is free from pebbles; but as it rises on to the plateau, and overlies the metamorphics, it becomes coarsely conglomeratic, made up principally of half-worn debris of the Shillong quartzite; and this bottom conglomerate is continuous from the scarp to the most northern outcrop. It has, however, been observed that the matrix at different levels partakes of the character of the corresponding horizon below Cherra; it is sometimes glauconitic, like the Mahádeo sandstone, and farther north it is locally calcareous, like the Lángpar rocks. The carbonaceous element is the most persistent; traces of it occur at the base of the cliff south of Cherra; and we have already mentioned the resin found mixed with marine fossils at the base of the series on the Jádukáta.

Cretaceous series: Garo area.—Immediately west of the Jádukáta, or Umblai, in the Hábiáng Gáro hills, Colonel Godwin-Austen has described[1] the cretaceous formation as made up entirely of sandstone, in which he could find no fossil remains, save indistinct vegetable impressions. Coal of serviceable quality and thickness was observed in many places; and attention is called (*l. c.*, p. 23) to this ground as the most favourable for an attempt to work the seams; as the formation here occurs at the very edge of the plains, within easy reach of water carriage.

From the figured sections in the paper referred to, it would appear that the overlap of the metamorphic rocks by the cretaceous sandstones is more gradual in this position than to the east or to the west.

From about the Jádukáta there is a slightly more northerly trend in the strike of the formations through the Gáro country, and this introduces a considerable expansion of the low fringing hills of upper tertiary strata; so that the line of the gneissic boundary emerges at Singmári, near the middle of the Assam range, where it terminates close to the

[1] J. A. S. B., XXXVIII, Pt. 2, p. 1.

left bank of the Brahmaputra. The importance of finding coal near the great river has led to the examination of the rocks in this neighbourhood.

The whole aspect of the Gáro hills is very different from that of the adjoining Khási country. In the latter the undulating uplands of the plateau are continued on the crystalline area, north of the horizontal sandstones; but the whole of the Gáro country is a maze of hills and valleys, with hardly any level ground, and all at a much lower elevation than the plateau country to the east. The leading feature of the area is a ridge of gneiss, coinciding with the line already indicated as the southern boundary of the metamorphic mass. It culminates in Nokrek, at an elevation of 4,652 feet; but is generally known as the Tura range, from the head-quarter station of the Gáro Hills district. It is important to notice that this ridge is not the watershed: the Sumesari (Soomeysurry) drains a large area to the north, passing through the ridge by a deep gorge above the village of Seju.

To some extent, at least, this contrasting condition of the two areas dates from precretaceous times. Even in the Khási hills the shallow basins of the cretaceous rocks shew a connexion with drainage lines that have been again selected by the present streams; but, on the whole, the surface of junction is more like a general plane of marine denudation. The coal-basins of Rongreng and Dáráng, on the upper Sumesari, north of the Tura range, are much larger and deeper. It will be shewn that they have undergone some special depression in tertiary times; but it is certain that they are original basins, for the cretaceous deposits thin out against the surrounding crystallines, overlapping the coal-seams on all sides. This more distinctly subaërial configuration of the crystalline surface in the Gáro area, at a present much lower elevation than that surface in the Khási country, is confirmatory of the conjecture, suggested by the position of the Sylhet trap, that the latter ground had undergone some relative upheaval.

Other more or less detached basins of cretaceous deposits occur to the west of the Sumesari, in the upper valleys of the Kálu and other streams, draining from north to south of the Tura ridge. West of Tura the crystalline rocks become very much lower, sinking to the level of the Brahmaputra at Singmári; and in this ground the sandstones are continuous across the prolongation of the ridge in many places.

The original relations of the rocks are nowhere better seen than here: the spur on which the station of Tura stands, some 2,000 feet below the crest of the ridge, has a midrib of gneiss, with sandstone on both sides, through which the streams have again excavated their

channels. There is little or no disturbance in this locality; and it is plain that the ridge must have stood as it does now when these sandstones were laid down. Thus it would seem that, at this west end of the Assam range, land and fresh-water accumulations of the cretaceous period had more or less enveloped the gneiss of the Shillong plateau, just as the Gondwána formations had covered up the corresponding rocks at the nearest point of the peninsular area, in the Rájmahál hills.

The earliest notice of coal in this ground (by Mr. James Bedford, Revenue Surveyor, in 1842) was in very shallow basins near the villages of Sálkura, Chámpagiri, and Mirámpura, on the low gneissic plateau south-east of Singmári. The seams are altogether valueless, being only carbonaceous shale, with small strings of resinous coal. It is certain that, so far as the formation is exposed on the western side of the field, there is a very marked decrease of the coaly element, compared with what is seen on the Sumesari, and between that and the Umblai, as described by Colonel Godwin-Austen; yet the rocks are the same throughout: a pale sandstone, in which only traces of plants have been found. A white shale, or pipe-clay, is of more frequent occurrence in the west. The most hopeful point in the enquiry is, perhaps, that the rocks are much more disturbed and exposed in the east than near the Brahmaputra; so that here the coal may lie concealed below the existing outcrops. In this connexion it is important to notice that, while in the Khási section all the beds in the low ground are marine deposits, the coal being confined to high ground at the north margin of the formation, in the Hábiáng Gáro hills, and on the Sumesari, at and below Seju, the coal is equally found to the south of the general gneissic boundary, in what may be called the main basin of the formation. Thus there seems a fair chance of finding it in a like position in the lower valley of the Kálu river.

Cretaceous series: Mikir area.—It is certain that the cretaceous rocks occupy a large space in the Jaintiá hills, where the features of the Khási area are continued for some distance; but we have no observations on that ground. To the east of it the distinctive characters of the formation become much disguised, probably through the substitution of earthy marine deposits for the coal-measure sandstone. The thin bands of hard sandstone, resting on the gneiss, at the falls of the Kopili, south of Nowgong, are supposed to be cretaceous; and the sandy limestone, similarly resting flatly on the gneiss, at the Námbar, near Golághát, is also believed to be of the same formation. In this river, a few miles west of Bor Patár, there is a bed of the typical cretaceous coal; and from the same neighbourhood in the Mikir hills, some white pipe-clay, just like that of Tura, has been sent in for inspection. Thus at its eastern

extremity, on the south-east border, the characters of the Shillong gneissic area, as a very ancient land surface that has undergone little or no disturbance, appear to be maintained.

Nummulitic series: Khasi area.—The northern thinning out of the nummulitic series upon the gneissic plateau is not so clearly seen, at least in the Cherra section, as in the case of the cretaceous rocks, because only remnants of the bottom bands are preserved there; but, on the whole, the evidence is convincing as to the southern expansion of the marine deposits. The nummulitics have not been observed anywhere to rest upon the gneiss, so there is no proof of their having overlapped the cretaceous deposits; but it is presumable that they did so, for the sequence is conformable, or at least parallel and undisturbed, on a rising surface of the metamorphics; and the nummulitics extend close up to the northern boundary, where the cretaceous beds are very thin, near the outcrop of the gneissic rocks.

Immediately to the south-west of the station of Cherra Poonjee there is a small plateau of nummulitic strata. The bottom 80 feet are of limestone, covered by about an equal thickness of sandstone, not markedly different from the underlying cretaceous rock. At about 10 feet above the limestone there is a thick seam of bright coal, the well-known Cherra coal.[1] The limestone rests directly upon the rough surface of the Cherra sandstone, without any sign of intervening denudation; and the bedding is parallel, having a southerly slope of 3°.[2] The fossils from this limestone were determined by Dr. Stoliczka: portions of the rock consist almost entirely of small specimens of *Operculina canalifera*, *Nummulites lucasana*, and *N. ramondi*, both the last species very small; also species of echinoderms, fragments of oysters, *Pecten*, *Cardium salteri*, and fragments of *Natica*, *Cerithium*, *Turritella*, &c.[3]

[1] Oldham: Mem. G. S. I., I., pp. 140 and 185.

[2] This little plateau at Cherra offers a remarkable instance of a form of denudation that is not, perhaps, taken sufficient account of in geological explanations. The scarp is very regular and well defined at many points; but the upper surface of the area, about a square mile in extent, is a chaos of tilted masses of the upper sandstone. This is clearly due to the more or less complete removal by solution of the supporting limestone. A small stream passes under the hill from north to south. The annual rainfall at Cherra exceeds 500 inches. Colonel Godwin-Austen (*l. c.*, p. 21) has described a much larger instance of this form of denudation in the Gáro hills, where a considerable enclosed catchment basin is drained underground.

[3] The fossils described from Eastern Bengal by MM. D'Archiac and Haime in their "Groupe Nummulitique de l'Inde" were all from the Khási hills; but their specimens were so mixed, probably even including fossils from the cretaceous beds, that the value of their identifications is doubtful. As the authors themselves remark—"On voit qu'il y a un certain vague dans les rapports de plusieurs des assises que nous venons d'indiquer:" *l. c.*, p. 177.

Close to the north of the coal hill, the nummulitic beds occur again in equal thickness, under the native town of Cherra Poonjee. The limestone is not seen here; but this may be partly due to concealment. The nummulitic sandstone forms the highest ground of the plateau from Cherra Poonjee to beyond Surarim. Carbonaceous markings are frequent in it; and at Lairangau, 4 miles north of Cherra village, there is a workable seam of coal. It is at about the same height over the cretaceous sandstone as the seam at Cherra; but at Lairangau the underlying beds are all sandstone and shale, except one bottom bed of limestone, resting on the Cherra sandstone. In this limestone bed *Operculina canalifera* and *Nummulites lamarcki* are very common; with these occur a *Trochocyathus, Stylocœnia vicaryi, Echinolampas spheroidalis*, a small *Cardita, Pecten, Natica rouaulti, Keilostoma marginatum*, a *Ziziphinus*, the small *Cerithium hookeri*, casts of a large *Natica, Cerithium*, and *Terebellum*.[1]

Under Surarim, only 1 mile from Lairangau, this bottom bed of limestone is wanting; and the carbonaceous sandstones themselves come to an end in a low bluff, 2 miles farther north, near where the road bifurcates. These observations clearly shew the entire replacement of a thick bottom band of marine limestone by a coal-bearing sandstone; or the latter may, perhaps, be more correctly described as overlapping the former.

The same character of the deposits is shewn by a comparison with the section at the foot of the hills. In the Tharia river the nummulitic series is as follows, all with a high southerly dip:—

	Feet.
7. Limestone, coarse, massive, blue	200
6. Sandstone, clear, yellowish, coarsish	100
5. Limestone, fine, compact, blue or pink	200
4. Sandstone, earthy, greenish, ochrey	50
3. Limestone	50
2. Sandstone, yellowish	100
1. Limestone	200
TOTAL	900

In the parallel section on the Bogapáni, below Chela, in the sandstone just over the bottom limestone, there is a coaly layer, which may sufficiently establish the identity of these two bottom bands with those on the plateau above, the marine bed having increased in thickness; and this marine character is here strongly stamped upon the whole series.

These nummulitic limestones form the most prominent features of the low hills at the foot of the scarp along the Khási area, where they

[1] These fossils were named by Dr. Stoliczka.

are in much greater force than elsewhere to east or west. This, as has already been suggested upon other grounds, may be owing to a greater elevation in this position, whereby a deeper zone of the basin of deposition has been exposed to view. Pure limestone is still the chief rock of the group on the eastern confines of the Gáro hills, west of the Umblai, as described by Colonel Godwin-Austen; although the total thickness must be much less than in the Tharia section. In the same ground this observer describes (*l. c.*, pp. 14 and 16) local cases of denudation-unconformity between the limestone and the cretaceous sandstone.

Nummulitic Series: Garo area.—On the Sumesari, however, only 12 miles farther west, a great change is observed. The whole series is exposed; but it contains only one thin band of limestone, about 40 feet thick, resting conformably upon the cretaceous sandstone. Even this limestone is often earthy, nodular, and ochreous, with shaly partings; the purer portion being generally formed of a mass of *Nummulites granulosa*, in various stages of growth. A similar change occurs throughout the formation: there are no clear sandstones; clays and soft earthy sandstones overlie the limestone, and are with difficulty distinguished from the succeeding upper tertiary deposits. This new character is still more pronounced at the west end of the hills. The clear cretaceous sandstone is well exposed in the gorge of the Kálu at Domalgiri below Tura; it is covered by crumbling brown clays, in which occur rusty earthy concretionary layers of nummulitic limestone, the only representative here of the pure rock of the Khási hills; and altogether the formation here strongly resembles the most characteristic beds of the Subáthu group in the North-West Himalayas. No coaly layer has been found in the series in the Gáro area.

The occurrence of remnants of the nummulitic group on the cretaceous sandstones of the interior basins north of the Tura range is a point worthy of attention. In the middle of the Rongreng basin some earthy nummulitic limestone was observed at the level of the river, the cretaceous rocks rising much higher against the surrounding metamorphics. The outcrop is flat and covered; but the presumption is that the local cretaceous group is complete there, and that the actual positions are mainly due to a later depression of these inner basins. There is sufficient independent proof that the crystalline rocks here were affected by the general disturbance, and that the east end of the Tura range must have been squeezed up to a considerable extent At both ends of the Sumesari gorge, in the Dáráng basin on the north, and at Seju on the south, the cretaceous strata rise nearly vertically against the gneiss, with the beds parallel to the contact; while rocks of the same age occur but little disturbed high on the shoulders of the intervening ridge, the width

at the base being about 4 miles. That there was an original ridge of smaller dimensions in this position is certain; and it seems equally so that the ridge underwent a subsequent special upheaval; and the manner of this upheaval seems to require an actual yielding and protrusion of the gneissic rocks. The disturbance which took effect as a general rise of the Khási area may have been concentrated here in this special crushing upwards of the east end of the Tura range. There is no trace of such an action at the west end, about Tura. Considering the view taken of the original relations of the rocks here, it is rather remarkable that the nummulitics have not been found anywhere in contact with the gneiss; but nothing like a survey of the ground has as yet been attempted.

Eastern extension of the nummulitics.—Having seen the steady increase of purely marine deposits from west to east for 120 miles in the Gáro and Khási areas, it might be expected that the more pelagic formation would be steady for some distance in the same direction, in what is represented as a still-expanding series of deposits. There is no doubt that the total sedimentary series in the Nága hills is much thicker than in the western areas; but it is almost exclusively made up of detrital (clastic) rocks, and it is certain that the increase takes place largely in the upper tertiary formations: the part taken by the lower tertiary (nummulitic) formation in the Nága hills is not known, and its extension in that direction on the map, to include the Upper Assam coal-measures, is still conjectural. The nummulitics of the Khási area no doubt continue for some distance into the Jaintiá country; but their mode of change or of extinction eastwards has not been traced out. Already on the track between Nowgong and Cachar they are so concealed or altered from their familiar aspect in the Khási section, as to have escaped the passing notice of an observer of some experience; and the more detailed examination of the ground in the Assam coal-measures at the north base of the Pátkai, has not revealed any recognisable outcrop of nummulitic strata. The explanation that has been offered of the change to the west may cover this case also: that a special elevation of the Khási area has there brought to the surface a deeper zone of deposits in this great continuous basin of deposition.

The upper tertiaries.—It was said above that at the west of the Gáro hills the earthy nummulitics pass up, without marked change, into the soft upper tertiary strata. There is at first a moderate southerly dip; but the strata become nearly horizontal as they recede from the gneissic mass; so that this section on the Brahmaputra is the most obscure of any in the whole range; the hills are much lower than elsewhere, and the tertiary series must have here a minimum thickness, even if the

whole of it is exposed. Yet the only distinct information we possess as to the horizon of these newer rocks is from this ground. In 1821 Mr. Colebrooke read to the Geological Society of London[1] some observations on these rocks by Mr. David Scott, then Commissioner of Cooch Behar. In those days the Brahmaputra flowed at the foot of the hills, and at one spot on the left bank Mr. Scott found some fossils. The exact locality is not given, but it was somewhere between the Kálu and Mahendraganj (or Karibári), probably nearer the latter place; so the position in the series is not known; but it seems certain that the bed belonged to the rocks of the hills, not to the "old alluvium;" for it is described as at the foot of a small hill, rising about 20 feet over the general elevation. The fossils were a strange mixture of marine with land and fresh-water forms; and amongst them Mr. Pentland described[2] the teeth of *Anthracotherium (Chœromeryx) silistrense*, a species that has been recently found in the Manchar (upper miocene) beds of Sind.[3]

The change of character that is so marked in the cretaceous and nummulitic deposits from west to east has not been observed in the upper tertiaries: there certainly can be no striking feature of this kind. A massive soft greenish sandstone is the most prominent rock; it is somewhat like the common Siwalik rock, but more earthy and of darker hue, and the associated beds are mostly grey shales, unlike the brown and ochrey clays of the Sub-Himalayan series; and the fossils above mentioned shew that even at this western end of the range the deposits are, in part at least, marine. In Mr. Scott's notes of the section on the Brahmaputra, local contortions are noticed, and this condition increases eastwards. On the Sumesari, where the tertiary zone is 14 miles wide, nearly 60 miles from the great river, the state of disturbance is still only partial[4]: at the southern edge of the hills the dip is 40° to the south, in very new-looking strata; there is then a broad band, in which the beds are flatly undulating; they then rise again with a steady and increasing southerly dip. The form of these outer, partial lines of disturbance is that of normal flexures, with the axis-plane sloping northwards, towards the gneissic mass at the edge of the basin (note, p. 528). In the inner half of the section there are two lines of compressed contortion, with intervening bands of nearly horizontal beds. In this more advanced state of compression the features suggest that the flexures had not been thrust over from the north, but from the south, as the reversed fault seems to have

[1] Trans. G. S., Ser. 2, vol. I, p. 132.
[2] Trans. G. S., Ser. 2, II, p. 393.
[3] Rec. G. S. I., X, p. 77.
[4] Mem. G. S. I., VII (193).

a southerly underlie, and the upthrow is on the south. Nothing like a general unconformity in the tertiary series was noticed in the section of the Sumesari.

Only 20 miles to the east lies the ground described by Colonel Godwin-Austen on the confines of the Gáro and Khási areas, where the upper tertiary rocks have been almost denuded away from the base of the range, the little that is left of them being nearly vertical. Several peculiarities have already been noticed in this position: the depression, or the gradual rise, of the metamorphic mass, unlike its abrupt southern ending to east and west: here, too, is the transition ground of the prevailing marine type of deposits in both the cretaceous and nummulitic strata, and here a partial unconformity was noticed between these formations. Similar conditions affect the upper tertiaries: this is the only position in the western part of the range where they have been found on the plateau, inside the line of disturbance. The summit of Nongkulang hill (2,070 feet) is formed of rusty sandstones and shales, resting horizontally upon the undisturbed nummulitic limestone. In a collection of fossils from these beds, sent by Colonel Godwin-Austen, Dr. Stoliczka found the genera *Conus*, *Dolium*, *Dentalium*, *Cardita*, *Cardium*, *Tellina*, *Nucula*, *Leda*, *Cucullæa*, and several others; and he remarked that none of the species, so far as recognisable, appeared to be identical with those known from the nummulitic beds of the same district. This fact suggests that these detached beds on the heights may, perhaps, be an overlap of some beds of the series higher than those that seem to be in transitional sequence with the nummulitics in the sections to the west. This view is strengthened by the fact, that Colonel Godwin-Austen observed some cases of local denudation-unconformity between these fossiliferous sandstones and the nummulitic limestone, the strata being still quite parallel.

Along the foot of the plateau in the Khási and Jaintiá areas the disturbed upper tertiary rocks have been almost entirely removed by denudation. East of Jaintiápur they appear again in force, and expand rapidly into the Barail range, which is, so far as known, entirely made up of them, rising steeply from the alluvial valley of Cachar, drained by the Surma, or Barák. On the south this valley is very undefined, long lateral valleys running up from it to the south, between the low meridional ridges of the Tipperah and Lushái hills, formed of the same soft upper tertiary rocks, some of which ridges strike up to within ten miles of the east and west Barail range. The Cachar valley seems to be excavated out of what must be the very broken ground where these two conflicting strikes meet. As the Barail curves to the north-east into the strike of

the Pátkai, north of Manipur, the confluence with the ridges from the south takes place more easily.

It is only in the north-east, in the Pátkai, that the range forms the main watershed. The northern drainage of the Barail passes through that range, by the deep gorge of the Jatinga, into Cachar. From the edge of the plateau, immediately over the upper Jatinga valley, the drainage flows to Assam. In this position the edge of the plateau, as constituted of horizontal rocks, does not visibly correspond with a supporting mass of metamorphics. There is here a large area of the North Cachar or West Nága hills formed of the massive upper tertiary sandstone very little disturbed. It would seem that the spill of the drainage took its origin here from the first great monoclinal axis of flexure into the basin of disturbance, the protrusion of the Barail range into its present position along that axis being a slow after-process. It seems not unlikely, too, that this great accumulation of late tertiary strata may be largely formed of early Himalayan debris, from the discharge of the great eastern torrents, the Dihong-Dibong, the Brahmaputra, and others; and that the diversion of these through Assam into Bengal was the result of the crushing together of those deposits in the lines of the Burmese mountain system.

The Assam coal-fields.—Upper and Lower Assam are very neatly defined geologically: the latter as the area between the metamorphic mass of the Shillong plateau and the Himalayas, where the metamorphics appear occasionally as outliers through the alluvium, and probably underlie the whole at no great depth. The most easterly known outcrop of these crystalline rocks, north of the Brahmaputra, is the granitic mass at Tezpur. Upper Assam lies on the north-easterly prolongation of the crystalline area, and commences at the Dhansiri valley, where the sedimentary series lying to the south of the gneiss extends beyond it, in the northern ridges of the Pátkai range, to form the south-east boundary of the upper part of the great valley. The general continuity of this line of outcrop here, with that of the crystalline boundary to the south-west, suggests that the metamorphics may extend for a long way beneath the alluvium of Upper Assam; but this is purely conjectural, and the data are insufficient to discuss it.

It has been already stated that, although these rocks of the Pátkai range are the direct continuation, after an unexamined interval of nearly 200 miles, of the formations already described on the southern margin of the Gáro and Khási hills, the general facies of the sequences are so different, that the two can only be correlated by a connected survey, fossil

evidence also being entirely wanting in the Nága ground. This eastern area must therefore stand by itself for the present. Mr. F. R. Mallet[1] has described the coal-measures in some detail, with the rocks immediately adjoining, for a length of about 100 miles from south of Jorhát. He gives the following classification of the formations:—

4.—The Dehing group (from the river of that name): conglomerates and blue clays with fossil wood; minimum thickness, 400 feet; transitional with No. 3.

3.—Tipam group (from the low range traversed by the Dehing above Jaipur): massive, false-bedded, soft, grey sandstones, with subordinate variegated clays and fossil wood; thickness, 7,000 to 9,000 feet; transitional with No. 2.

2.—The coal-measures: alternating shales, sandstones and coal, with a few thin calcareous layers; thickness more than 2,000 feet.

1.—The Disang group (from the river of that name): grey, fine, hard sandstones overlying splintery grey shales, several thousand feet thick.

General structure.—Although in a general sense the section of the Pátkai may be, as suggested, a continuation of that to the south-west, with a prolongation of the crystalline rocks beneath the Upper Assam valley, very great changes are introduced to the north-east. Instead of finding the lowest rocks at the base of the hills, adjoining the alluvial area, as would be the case on the simple supposition referred to, there is, on the contrary, a nearly continuous belt of upper tertiary rocks outside (north-west of)[2] the main outcrop of the coal-measures and of the Disang group. This feature is due to a great fault that has been traced from end to end of the area, with a steady strike to east-35°-north, and having a great upthrow to the south-east. On both sides of the fault the prevailing dip is towards the crest of the Pátkai.

This fault is the leading structural feature of the field, and it must have a throw of from 10,000 to 15,000 feet; for the outer tertiary rocks dip towards it, and high Tipam, and even Dehing, beds are generally found at the dislocation in contact with the Disang group. The principal coal-fields occur isolated inside the great fault, where, at intervals, the throw is less, or where a loop-fault encloses a section of the measures. Here, too, south of the main fault, the Tipam group is found in force overlying the coal group, and proving the magnitude of the dislocation. Thus the several coal-fields inside the fault are strictly isolated as basins of dislocation. The only position where the coal-measures appear at the base of the Tipam group outside the fault is in the Jaipur field, on the Dehing and the Disang; but they presumably occur all along the margin

[1] Mem. G. S. I., XII, p. (269).

[2] See note, p. 529: the axis of disturbance here is not Himalayan, but that of the Burmese system.

of the alluvium, at an unknown depth: the great thickness of the Tipam group would make the search for the coal very precarious, unless near a known outcrop.

The Disang group.—The three upper groups form a continuous sequence, and the top one is a very late tertiary formation, so the Disang beds must take their place below the continuous series, as at least older than the coal-measures. The Disang boundary is everywhere described as faulted, and the original base of the coal-measures has not anywhere been observed: it is, however, quite probable that the Disang beds also form part of the continuous sequence, for both shales and sandstone are very much like those of the coal-measures; only in the latter these rocks are freely interbedded throughout, and include coal-seams at all levels; whereas in the Disang group the shales, as a whole, underlie the sandstone, and both are without carbonaceous layers. As these contrasting conditions obtain in contiguous areas, it is impossible the groups can be the same; and the Disang is certainly the older.

The type section of the group is taken from the Disang, south of the Tipam range, no coal-measures being exposed along the great fault for many miles on either side; but similar rocks occur to the south of the coal-measures, in the Mákum field, to the east, and in the Názira field, to the west.

The coal-measures.—Three principal fields have been described. In the Jaipur field the measures crop up with a high dip along a narrow band at the north base of the Tipam range for about 20 miles, when they are covered over in both directions by the alluvium. East of the gorge of the Dehing, at Jaipur, the Tipam range comes to an end, and the alluvium passes behind it, up to the edge of the Mákum field, along the main fault. This is the most extensive of the Assam coal-fields: to the south-west its exact limit is not known, but it is certainly cut out before reaching the Disang; to the north-east it extends beyond the limits of exploration, into the Singpho country. The Názira field occurs along the great fault, on the Dikhu and Saffrai rivers, for a length of about 16 miles. In the former position the outer hills of the Tipam rocks intervene between the plain and the coal rocks; but on the Saffrai the ground is more open, and the coal-field moreaccessible. Farther to the south-west there are small outcrops of the coal-measures south of the fault, on the Jánji and Disai rivers; but here the outer range of Tipam rocks is very broad, and the coal proportionately difficult of access.

For detailed information regarding these fields and the coal, we must refer to Mr. Mallet's memoir.[1] The measures are very much alike in all;

[1] Mem. G. S. I., XII, Pt. 2.

seams of less than a yard in thickness are very numerous in some sections, and not unfrequently the coal beds attain much greater dimensions. In the Námdáng, south of Rongreng in the Mákum field, there is a seam 100 feet thick, containing at least 75 feet of solid coal; and some very large seams have been traced for more than a mile without diminution. The sandstones and shales often contain nodules and layers of clay-ironstone. Earthy and ferruginous limestone occurs sparingly in thin concretionary bands, also some layers of hard tough magnesian limestone. The coal-measure shales decompose into a very tenacious blue clay, differing in this respect from the Disang shales, which are more clunchy.

On the interesting question of the age of these very important and extensive coal-measures, there is little evidence for opinion; and that little suggests a middle tertiary horizon. The coal itself is a true coal of superior quality, not lignite, as is attested by its composition.

	Fixed carbon.	Volatile matter.	Ash.
Average composition of 27 Assam coals .	60·0	36·2	3·8
Ditto of 17 Raniganj coals .	51·1	32·6	16·3

It is not unlike the nummulitic coal of the Khási hills, and quite unlike the cretaceous coal, which maintains its peculiar characteristics into close proximity to the Assam fields. The only fossils found in the seams are bad impressions of dicotyledonous leaves; and no trace of animal life has been seen in any of the associated rocks. The strongest point in the argument is the closely transitional relation between the measures and the Tipam sandstone, which is a very typical representative of the Siwalik rock, and almost undoubtedly belongs to that upper tertiary period. In the Khási hills, and again in the Punjab, the nummulitic coal occurs near the very base of the formation: in the Tharia section (p. 694) there are about 1,000 feet of marine nummulitics above the coal bed. If the Upper Assam coal-measures are nummulitic at all, they would seem to belong to the upper limits of the formation.

Tipam and Dehing groups.—We might without much risk speak of these as Lower and Upper Siwaliks; for in very many respects they correspond with those Sub-Himalayan formations as seen on the north side of the alluvial valley; and it is by no means improbable that the two may yet be traced into actual continuity through the wild unexplored country at the head of the valley. The greenish grey (pepper-and-salt) sandstone of the Tipam range undoubtedly alternates with the top beds of the coal-measures; but the shaly beds rapidly cease, and the sandstone becomes very massive. Some coaly partings were also observed well up in the Tipam group; and fossil wood, whether silicified or semi-

CHAPTER XXIX.

EXTRA-PENINSULAR AREA.

BURMA.

Area and physical geography — Geological data —Rock-groups — Metamorphic rocks — Mergui group — Maulmain group — Axial (triassic) group — Mai-i (Cretaceous) group — Supposed cretaceous coal in Tenasserim — Negrais rocks — Serpentine — Nummulitic group — Arakan — Coal-bearing rocks of Tenasserim — Pegu group — Newer tertiary beds in Arakan — Pliocene fossil-wood group — Tertiaries of Upper Burma — Extinct volcano of Puppa — Trachyte in South-Western Pegu — Post-tertiary deposits: laterite — Older alluvial sands and gravels — Delta of Irawadi — Littoral concrete of Arakan coast — Mud volcanoes of Rámri, &c. — Islands in the Bay of Bengal — Andamans — Nicobars — Barren Island and Narcondam.

Area and physical geography.—British Burma, consisting of the countries on the eastern side of the Bay of Bengal, north of the tenth parallel of north latitude, comprises three divisions—Arakan, Pegu, and Tenasserim. The first and last of these are mainly composed of narrow strips of territory extending along the coast; the former north, the latter south, of the Irawadi delta. Pegu consists of the lower Irawadi valley, south of the parallel of 19° 30′ north latitude, together with the country between the Irawadi and Sittoung (or Sitang) rivers. Martaban, part of the Tenasserim division, includes a large tract between the Sittoung and Salwin.

The whole region is traversed by hill ranges, having a general north and south direction, parallel to the coast. All the principal streams have the same general course, which is the strike of the rocks. To the northward, in Arakan, the strike curves to west of north.

The main hill ranges of British Burma are three in number. Commencing to the westward, the ridge running parallel with the coast, and forming the watershed between the Bay of Bengal to the westward, and the Irawadi valley to the east, is known as the *Arakan Yoma*.[1] This range is the southern continuation of the somewhat complicated ranges to the east of Chittagong; it becomes a well-defined ridge of great

[1] *Yo-ma* is a Burmese word signifying backbone.

breadth, but of comparatively moderate height, east of Akyab, and continues steadily to Cape Negrais. To the northward the general height of the watershed is about 3,000 to 4,000 feet, some peaks rising to as much as 5,000; but to the southward the elevation is much less. This range is the boundary between Pegu and Arakan.

East of the Irawadi valley, and forming the water-parting between that river and the Sittoung, is another range, known as the *Pegu Yoma*, terminating to the southward, close to Rangoon, and extending northward for some distance beyond the British frontier. The maximum elevation of this Yoma is about 2,000 feet, and is attained near the southern extremity, in latitude 17° 55′; thence northward to the frontier the height of the watershed varies from 800 to 1,200 feet.

The whole of the mountains east of the Sittoung must be classed with those of the Tenasserim provinces as parts of one great range, greatly exceeding the Arakan and Pegu Yomas in elevation, and distinguished from both by being mainly composed of metamorphic rocks. To the northward this range, which appears to have no general and distinctive name, is connected with the gneissic ridges and plateaus of Upper Burma; it forms the watershed between the Sittoung and Salwin, the latter river cutting through it near Maulmain (Moulmein), where the strike of the rocks is north-north-west instead of north, and it continues as a number of parallel north and south ranges in the Tenasserim provinces. Towards the southern extremity of British Burma the various parallel ridges coalesce into one general range, which forms the backbone of the Malay Peninsula. The metamorphic hills frequently attain an elevation of 5,000 to 6,000 feet, and some peaks are said to be as much as 7,000 above the sea.

It may be useful to notice that the great rivers of British Burma are the Irawadi and Salwin, both of which rise far to the northward, in Chinese territory. The Sittoung is a much smaller stream, coming from but a short distance north of the British frontier. The Irawadi forms a large delta, but the Salwin flows in a rocky channel almost to its mouth. In Northern Arakan are several rivers of considerable size, the principal being the Koladyne, all running from the northward; and in the Tenasserim provinces, the river Tenasserim has a course of about 150 miles from north to south, before turning westward to run into the sea near Mergui. The general parallelism of all the streams and hill ranges gives an appearance of simplicity to the physical geology of the country; but, owing in a great measure to the prevalence of forest, it has been found extremely difficult to determine the stratigraphy, and very little can be said to be accurately known about the formations occurring.

Geological data.—The province of Pegu has been geologically mapped[1]; but, for the reason mentioned, the classification of the rocks in the hill ranges is by no means satisfactorily settled. The formations along the course of the Irawadi north of the British frontier to beyond Ava have been cursorily examined,[2] as also a tract on the upper Salwin[3]; and the extinct volcano of Puppa, south-west of Pagán, has been visited.[4] Occasional notes, too, have been collected by various travellers in other parts of Upper Burma. A few visits have been made to parts of Southern Arakan in the neighbourhood of Pegu, and to the islands of Rámri and Cheduba,[5] the southernmost part of Arakan being included in Mr. Theobald's map of Pegu, but the northern portion of the division is geologically unknown. All that can be said is, that the formations are probably similar to those of the Arakan Yoma, as the same beds appear to extend northward into the Assam hills. Tenasserim is similarly most imperfectly known, the neighbourhood of Maulmain, and a few localities to the southward, being the only parts of which any account exists.[6]

Rock-groups.—The following are the groups in which the rocks found in Burma have been arranged, with their approximate geological position. It should be repeated that, owing to the very great difficulties in the way of a geological exploration of the country, the sub-divisions are by no means so well defined as in the Peninsula of India. The fossils found have not been compared and described; and until this has been done, it is impossible to feel sure that portions of different groups have not, in some cases, been included in one sub-division.

Name.	*Rocks.*	*Supposed geological age.*
I. NEWER ALLUVIUM, &c.	Blown sand, littoral concrete, regur, and recent alluvial deposits.	*Recent.*
II. OLDER ALLUVIUM .	Sand and gravels of the older river alluvium, laterite, &c.	*Post-tertiary.*
III. FOSSIL-WOOD GROUP .	Sand, gravels, &c., with silicified wood and bones of *Mammalia.*	*Pliocene.*

[1] Theobald: Mem. G. S. I., X, pp. (189)—(359). Some earlier notices appeared in the Records of the Geological Survey of India, but all details were incorporated in the Memoir quoted.

[2] Oldham: Yule's Mission to the Court of Ava, Appendix, pp. 309—351.

[3] By Mr. Fedden.

[4] J. A. S. B., 1862, XXXI, p. 215.

[5] Mallet: Rec. G. S. I., XI, pp. 188—223.

[6] Oldham: Selections from the Records of the Government of India, Home Department, No. X, pp. 31—67.

	Name.	*Rocks.*	*Supposed geological age.*
IV.	PEGU GROUP	Shales and sandstones, occasionally calcareous; fossils numerous.	*Miocene.*
V.	NUMMULITIC	Shales and sandstone, with some limestone bands containing nummulites, &c.	*Eocene.*
VI.	NEGRAIS ROCKS	Similar, but much hardened, and sub-metamorphic in places.	*Eocene* or *Cretaceous.*
VII.	MAI-I GROUP	Limestone, sandstone, calcareous shales, &c., with *Ammonites inflatus.*	*Cretaceous.*
VIII.	AXIAL GROUP	Shales, sandstones, &c., more or less altered, and occasionally schistose.	*Triassic.*
IX.	MAULMAIN GROUP	reddish sandstone, and shales.	*Carboniferous.*
X.	MERGUI GROUP	Slaty and schistose beds, grits, &c.	?
XI.	METAMORPHIC	Gneiss, mica-slate, &c., with granite veins.	*Azoic.*

INTRUSIVE ERUPTIVE ROCKS.—Serpentine, trachyte, &c.; an extinct volcano in Upper Burma.

Of these various groups, it should be stated at once that the three uppermost constitute the greater portion of the Irawadi valley; that the Pegu Yoma consists entirely of the miocene Pegu group; and that the Arakan Yoma, and the spurs to the eastward and westward of the main range, are chiefly composed of nummulitic, cretaceous, and triassic beds. The carboniferous limestone and its associated beds, together with the Mergui group, are, in British Burma, nearly confined to the Tenasserim provinces; the former extending northward into Martaban, whilst the main area of metamorphic rocks lies to the east of all the other formations. In describing the various beds, it will be best, as usual, to commence with the lowest; the intrusive rocks, however, being noticed with the beds with which they are associated.

Metamorphic rocks.—The Burmese gneissic series consists of more or less granitoid gneiss, hornblendic gneiss, crystalline limestone, quartzite, and schists of various kinds. In many places the gneiss becomes a true granite, and much of the area occupied by the crystalline formations has been described by various observers as composed of granitic rocks. Some of the granitoid portions of the rock weather into remarkable rounded masses,[4] isolated from each other by the decomposition of the intervening rock, and forming huge piles of gigantic boulders, as in Southern

[1] Figures of some extraordinary isolated blocks of this kind, resembling perched erratics, but really due to disintegration, are given by the Rev. C. Parish in his "Notes of a trip up the Salween," J. A. S. B., 1865, XXXIV, Pt. 2, pp. 135, &c., Pl. VI, VII, VIII.

India (Hyderabad, Mysore, &c.) and parts of Western Bengal.[1] Hornblendic gneiss seems less abundant than in the main gneissic area of India, whilst crystalline limestone is of not uncommon occurrence.

So little attention has hitherto been paid to the metamorphic rocks of Burma, that very little is known of the minerals occurring amongst them. That the gneissic formations are metalliferous in places has long been known; gold is obtained, in small quantities, in many of the streams, and tin stone is found in some abundance in parts of the Tenasserim provinces and in Martaban. Lead and silver mines, one of them at least—the famous Bau-dwen-gyee—of very large dimensions and highly productive, exist in the Shan States, north-east of Ava. The most valuable and productive ruby mines known are in the same direction, but nearer to the capital. Chondrodite associated with spinel in crystalline limestone has been found close to Mandalay, the combination of minerals being similar to that occurring in certain localities near New York.

As already mentioned, metamorphic rocks occupy a large, but unexplored, area in Upper Burma: they form all the higher ranges in the neighbourhood of Ava, and extend throughout a great portion of the country, extending thence to the Salwin. Farther to the northward they extend from Bhamô to the neighbourhood of Momein in Yunnan.[2] The Irawadi below Ava turns more to the west, and flows through newer rocks, whilst the crystallines continue to the southward, forming the Red Karen (Karen-ni) country and the hills between the Sittoung and Salwin, and extend into Tenasserim. None occur in Pegu or Arakan, west of the range between the Sittoung and Salwin.

It is impossible to do much more than guess at the relations of the Burmese metamorphic rocks to those of the Indian Peninsula; but the gneissic rocks of Burma have more resemblance to those of Peninsular India than to the crystalline formations of the Himalayas.

Mergui group.—Resting upon the metamorphic rocks in the southern portion of the Tenasserim provinces, there is a great accumulation of pseudo-porphyritic sedimentary beds, the principal feature of which is derived from imbedded crystalline fragments of felspar. The rock in its normal form is earthy, but highly indurated; it passes, on the one hand, into slaty masses without the conspicuous felspar fragments, and on the other into grits and conglomerates. With these grits, and resting upon them, are dark-coloured earthy beds, finely laminated, with hard quartzose grits. These rocks cannot be less than 9,000 feet in

[1] A form of "dome gneiss;" see *ante*, p. 20.

[2] Anderson: Report on the Expedition to Western Yunnan, Map.

thickness, and in places they must be 11,000 or 12,000. They have only been noticed hitherto near Mergui, and nothing is known of their relations.

Maulmain group.—The beds of the last group in the Tenasserim valley are succeeded, in ascending order, by hard sandstones, often in thin and massive layers, with thin earthy partings, sometimes in fine laminæ; the prevailing colour is a reddish tint, and some of the layers are calcareous. Some of the more soft and earthy beds contain marine fossils. Over these sandstones occur grey shaly beds, also sometimes calcareous and fossiliferous, with occasional beds of dark sandstone; then come 150 to 200 feet of fine soft sandstone, thinly bedded with grey and pinkish shaly layers intercalated; and upon these, again, hard thick limestone. The fossils found are unmistakably of carboniferous age, *Spirifer* and *Productus* being the commonest forms; but the species have not been determined, and it is rare to obtain specimens in a state suitable for identification.

The thickness of the Maulmain group, exclusive of the limestone, is estimated at about 5,000 feet, and the limestone itself near Maulmain is 1,100 feet thick.

Near Maulmain the limestone is extremely conspicuous, and forms large hills and ranges, extending far to the south-south-east up the valley of the Ataran and Zami. The same rock occurs east of the Salwin, but it does not extend far into Martaban, and it is wanting in the Sittoung valley. Farther up the Salwin, however, in Karen-ni, and elsewhere beyond the British frontier, large tracts of limestone occur, probably belonging to the carboniferous series. Limestone is said to abound in the Mergui Archipelago, and may very probably be, in parts at least, identical with that found near Maulmain. Carboniferous limestone is also extensively developed in Sumatra.[1]

Until the fossils are better known, it is impossible to say whether the Maulmain group exactly corresponds to the carboniferous beds of the Himalayas and the Punjab; there can, however, be no question that both are of the same approximate age. The occurrence of marine fossiliferous rocks of the carboniferous period at the two extremities of the extra-peninsular area of British India, and the complete absence of any marine palæozoic fossils within the peninsular region, afford perhaps one of the most striking illustrations of the great divergence between the geological history of Peninsular India and that of the surrounding countries.

[1] Geol. Mag., Dec. II, Vol. II, p. 478.

Axial (triassic) group.—There is manifestly a great break between the rocks already noticed and the mesozoic formations of Burma; the older beds are found in a distinct area to the eastward, and are associated with metamorphic rocks, whilst the triassic beds are only known to occur west of the Irawadi, and are connected by stratigraphy and position with the newer rocks of the Arakan Yoma range. This range, although of no great height, forms an excessively broad belt of uninhabited forest-clad hills, only traversed by a single road and by a few difficult paths at wide intervals, and it is, in general, absolutely inaccessible, except along the tortuous beds of streams. Anything like satisfactory geological surveying becomes almost impossible in such a region, unless some well-marked and prominent beds occur to afford a clue to the stratigraphy, or fossiliferous belts are numerous. In the Arakan range neither is the case; the rocks of the main range consist of rather hard sandstones and shales, greatly squeezed, contorted and broken, traversed by numerous small veins of quartz, often slaty, and sometimes schistose; but there is a marked deficiency of any conspicuous strata. The few bands of limestone which occur are thin, isolated, and as a rule unfossiliferous. The rocks on the western, or Arakan, side of the range appear, on the whole, less altered than those on the eastern, or Pegu, slope; and on the outer spurs, on both sides, unaltered nummulitic rocks appear throughout a great part of the area, although not continuously.

The crushed, hardened, and somewhat altered rocks of the Arakan Yoma were originally separated by Mr. Theobald from the newer-looking nummulitics under the name of "axials," and considered as comprising the oldest tertiary beds and their immediate predecessors in the series. Although there is a well-marked difference between the nummulitic beds and the "axials," there is no distinct break between them; the two present an appearance of conformity where they are not faulted against each other, and it is far from clear that some of the axials are not merely nummulitic strata, greatly crushed and contorted. But subsequently to the preliminary examination of the area, a cretaceous ammonite was found in Arakan; and amongst some rather obscure fossils discovered near the frontier of British and Native Burma, west of Thayetmyo, were a few specimens referred by Dr. Stoliczka to the typically upper triassic *Halobia lommeli* (Pl. II, fig. 5). It became, therefore, necessary to distinguish both triassic and cretaceous beds amongst the axial rocks of the Arakan range.

To the former has been referred a series of hard sandstones and shales, with grits and conglomerates, and a few bands of impure limestone, which form the crest of the Arakan range at the frontier, and extend to the

southward, nearly to the parallel of Prome. The only characteristic beds are some white-speckled grits, interbedded with shales and sandstones, and attaining a thickness of 1,300 feet, in the Lhowa stream, 35 miles west of Thayetmyo; a band of dark-blue shale with conglomerate, part of which is calcareous, 33 feet thick, below the grits; and some thick-bedded shales, passing into massive sandy shales, with hard nodules interspersed, attaining a thickness of 110 feet, and containing a *Cardita* and some undetermined *Gasteropoda*. The calcareous conglomerate passes into a rubbly limestone, and appears identical with the beds containing *Halobia lommeli*. To the northward a band of limestone, much thicker and purer than that of the Lhowa stream, has been traced in several places. The speckled grits and conglomerates are, however, more conspicuous and more characteristic, and it is mainly by means of them that the area of supposed triassic beds has been mapped.

The whole thickness of the triassic group appears to be rather less than 6,000 feet, the characteristic beds just noticed being near, but not at the base of the group. To the eastward these beds are in contact with nummulitic strata, the boundary having the appearance of a fault; to the westward it is believed that cretaceous beds come in, but the country is difficult of access, and has not been surveyed. The area occupied within the limits of British Burma is elongately triangular, broadest at the frontier, where it extends for 15 miles from east to west, and terminating in a point to the southward, west by north of Prome.

A few outbursts of serpentine occur within the limits assigned to the triassic group. As these intrusive masses differ in no way from some occurring farther south, amongst the rocks of the Negrais group, it will be best to notice all the cases of serpentine intrusion together.

Mai-i (Cretaceous) group.—The existence of cretaceous beds in the Arakan Yoma, like the occurrence of triassic strata, is only shewn by the discovery of one species of mollusk in a single locality in Arakan; the species found, *Ammonites inflatus*, is a characteristic cenomanian cephalopod, common in the Utatúr beds of Southern India. The only specimen obtained was picked up in the bed of a stream, and had evidently been derived from some shales in the neighbourhood. No other specimens nor other fossil of any kind could, however, be found.

The spot where this ammonite was found was near Mai-i, in the northern part of the Sandoway district of Arakan.

What may be the extent of the cretaceous beds, and which strata should be referred to this group, are matters on which but little trustworthy information has been obtained. Mr. Theobald is disposed to consider that a peculiar, compact, light cream-coloured argillaceous limestone,

resembling indurated chalk, sometimes speckled from containing sublenticular crystalline particles, belongs to the cretaceous formation ; and this limestone has been traced at intervals from near Mai-i, about 30 miles north of Tongúp (Toungoop), to the neighbourhood of Sandoway, whilst somewhat similar limestone, though not so characteristic, may be traced to Keantali, some 30 miles farther south. The same limestone is found in the western part of Rámri Island. Another peculiar formation is a greyish, rather earthy sandstone, with, in places, a pisolitic structure, due to the presence of small globular concretions of carbonate of lime and iron. The concretions decompose, and leave small holes, which impart to the earthy sandstone the aspect of an amygdaloidal trap. Like the limestone, this peculiar sandstone is traced from Mai-i to near Keantali, a distance of 94 miles; and if, as appears probable, these beds are really cretaceous, for both are closely associated with the shale from which the ammonite had apparently been derived, the rocks of this formation may be considered as extending at least the distance mentioned. To the northward their range is unknown; to the south, they seem to be replaced by the next group, which may, however, in part at least, be simply the same beds, but more altered. The strata ascribed to the cretaceous group are less hardened and metamorphosed than the other rocks of the Arakan Yoma; they are of great thickness, and may include all the beds to the west of the triassic group, and of the main range of the Yoma as far south as Keantali. No rocks which can be referred to the Mai-i group have been detected east of the main Arakan range in Pegu.

Supposed cretaceous coal in Tenasserim.—There is, however, some probability that cretaceous rocks may exist in Tenasserim. On the Lenya river,[1] in the extreme south of the province, a bed of coal occurs, of very laminar structure, and containing numerous small nodules of a resinous mineral like amber. This peculiar association of mineral resin is characteristic of the cretaceous coals in the Assam hills, and it is highly probable that the Tenasserim mineral is of the same age. At the same time no palæontological evidence has been discovered; the rocks associated with the coal are soft clays and sands, having a more recent appearance than those accompanying the other coal-seams of the Tenasserim provinces; and these other seams are, it is believed, not older than eocene. The coal occurs as an irregularly developed bed, varying from one to five feet or rather more in thickness, with thin layers of fine jetty coal between bands of hard black shale, and rests upon clay with vegetable remains, also containing patches of jet-coal; thin coal laminæ are also found in the associated strata.

[1] Oldham: Sel. Rec. Govt. India, Home Dept., No. X, p. 48.

Below the rocks, immediately associated with the coal, are fine, whitish, earthy sandstones and indurated clay, passing into marl, with some conglomerates. Above the coal is a series of soft muddy sandstones, clays, marls, conglomerates, and a few seams of carbonaceous matter. The whole may be 600 feet thick. The dip is considerable, about 35°, and the rocks have undergone disturbance and faulting. Nothing has been ascertained as to the relations of the coal-bearing beds to other formations; indeed, all that is known of the Lenya river coal is the result of a hurried visit to a locality very difficult of access.

Negrais rocks.—The remainder of the rocks forming the Arakan Yoma are either unfossiliferous, or the few organisms which have been detected, mostly indistinct remains of plants and mollusca, are insufficient to afford any trustworthy indication of age. Some of these rocks appear to be a continuation of the Mai-i group; whilst, on the other hand, it is impossible to draw any definite line of boundary between the hill rocks and the nummulitics of Pegu. In Pegu, away from the base of the hills, comparatively soft, unaltered fossiliferous beds are found, belonging to the older tertiary period; these strata appear to rest upon the hill beds; for, away from the axis of the range, both have, in general, an eastwardly dip. The two rocks contrast strongly, the nummulitics being soft and unchanged, the hill beds hardened, crushed, and in places almost schistose; but it is impossible to find a precise limit to either; the two are never seen in contact; there is no evidence that they are faulted against each other, and there appears to be a belt, often two or three miles wide, of rock in an intermediate condition. On the whole, it appears probable that the rocks of the Arakan Yoma in general comprise representatives, slightly altered, of both cretaceous and nummulitic rocks; but as it has hitherto proved impossible to draw a line between the two, whilst, on the other hand, there is no clear proof that these Arakan Yoma beds are identical with the Pegu nummulitics, it appears best to distinguish the hill rocks by a separate name, and to class them, as Mr. Theobald has proposed, as Negrais rocks. The name is derived from Cape Negrais, the south-western point of Pegu, and the extreme southern termination of the Arakan Yoma.

The Negrais rocks differ in no important particulars from the triassic and cretaceous beds, already noticed, except that they are more altered than the latter. They consist principally of hardened and contorted sandstones and shales, intersected throughout by numerous small veins of quartz and carbonate of lime. Limestone is not of common occurrence; where it is seen, it does not appear generally in regular strata, but in huge detached blocks, imbedded in the shales and sandstones, as if the

latter had yielded without fracture to the pressure which dislocated the limestone. Conglomerates also occur, sometimes passing into breccia.

The alteration of these beds is most capricious and irregular; frequently for a long distance they are apparently unchanged, except in being somewhat hardened; then they become cherty, slaty, or sub-schistose, and cut up by quartz veins. One not uncommon form of alteration is exhibited by the rocks affecting a greenish hue, due to the presence of chlorite, such rocks being generally much cut up by quartz veins. In a few instances, apart from the serpentine intrusions to be mentioned presently, irregular dyke-like masses of either serpentine or a decomposed steatitic rock are found; but this is far from being of frequent occurrence. A more common form of alteration seen along the coast north of Cape Negrais is apparently due to the infiltration of silica in large quantities, and is shewn by the intense, and often abrupt, alteration of beds of sandstone into cherty masses.

No satisfactory classification of these, the main rocks of the Arakan Yoma, has been practicable; they must be of great thickness, but the stratification is too confused, in the absence of any well-defined horizon, for a clear idea as to the succession of different strata to be formed. Some massive sandstones on the Arakan coast north of Cape Negrais may perhaps be high in the series; they are little, if at all, altered, and dip westward at a low angle. They are of a peculiar greenish hue, and comprise subordinate bands of conglomerate, containing fragments of indurated shale and some quartz. It is possible that these sandstones may be nummulitic; but as it is almost certain that some of the Negrais rocks are older tertiary, the separation of the upper beds is useless without further evidence.

Serpentine.—The occurrence of masses of serpentine has already been noticed; the intrusive rock generally occurs as irregularly-shaped bosses of varying dimensions,[1] but, especially north-west of Prome, dykes also occur. The rock is a characteristic dark-coloured serpentine; it frequently becomes a gabbro, and contains bronzite, and it is intersected by veins of gold-coloured chrysotile, or sometimes of carbonate of magnesia. Occasionally it appears to be replaced by a form of greenstone; or possibly the greenstone outbursts may be distinct, although the two rocks occur in the same neighbourhood. The hills formed of serpentine may be distinguished at a distance by their barrenness; they appear to support little except grass and a few bushes; the greenstone hills, on the other hand, are covered with luxuriant forest. In all probability, the serpentine and greenstone outbursts were originally the

[1] None are sufficiently large to be marked on the map issued herewith.

same, or nearly the same, and the former rock has undergone a chemical change.

In the neighbourhood of some of the larger masses of serpentine, the sandstones and shales are converted into greenstone and chloritic schist; but the effect varies, and in some instances the neighbouring rocks appear almost unaltered. It is, however, worthy of notice that, except far to the northward, all the outbursts of serpentine appear confined to the Pegu, or eastern, side of the range; and that, as has already been stated, the rocks on the Pegu side exhibit, as a rule, more alteration than those on the western slopes in Arakan. To the northward, near the northern frontier of Pegu, serpentine occurs on the highest hills of the Yoma, and, in one instance at least, on the western side; but elsewhere all the outbursts detected are not only east of the main range, but near the eastern limit of the hill rocks. Not a single intrusion has been detected in the unaltered nummulitic rocks.

It is unnecessary to describe the distribution of the serpentine masses in any detail. They are principally collected in three groups, the most northern of which consists of the largest mass known, a horse-shoe shaped intrusion, some 5 miles in length, forming Bidoung hill, amongst the triassic rocks, nearly due west of Thayetmyo. Several masses occur north-north-west of Prome, in the southern portion of the triassic area; and one of these, forming a long dyke-like mass, running for about 5 miles along the boundary between nummulitics and trias, appears to alter the triassic rocks, but not the nummulitic beds, although the latter are greatly crushed. Probably, the difference is owing to the boundary between the serpentine and nummulitics being a fault. The third group is west of Henzada, where twenty-one distinct and isolated intrusions occur, scattered over a length of 26 miles from north to south, close to the edge of the unaltered nummulitic area. The largest of these masses is about 3 miles long by perhaps half a mile broad; but the majority are less than a mile in diameter. Besides these principal groups, a few small and unimportant outbursts are found isolated here and there; none, however, are found south of the area west of Henzada.

Nummulitic group.—Beyond the much smaller amount of alteration that they have undergone, and the resulting difference in mineral character from the hill rocks, there is but little to distinguish the nummulitic beds of Pegu from the Mai-i and Negrais rocks, except the more frequent appearance of fossils, and the occasional occurrence of limestone containing nummulites, especially in the higher part of the group. The ordinary beds are sandstones and shales, unaltered, but still frequently hard and compact. The distinction from the Negrais rocks is far from

absolute; the tendency to a passage at the foot of the hills has already been noticed, and there are, in places within the nummulitic area, hills formed of hardened masses, perhaps older than the rocks around, but which have much the appearance of being the same beds, slightly altered.

The main outcrop of the nummulitic rocks extends from north to south throughout the province of Pegu, east of the Arakan hills, and west of the Irawadi river. The beds have a general dip to the eastward: but to the southward it is difficult, if not impossible, to define the base of the formation, on account of the apparent passage, just noticed, from the nummulitic into the Negrais rocks. To the northward, west of Thayetmyo, near the boundary of British territory, the section is better defined, the lowest eocene strata, however, being, to all appearance, faulted against the triassic rocks; so that here, again, it is uncertain whether the bottom beds of the tertiary series are exposed. In the Lhowa stream, 16 miles west by south of Thayetmyo, upwards of 4,000 feet of hard sandstones, mostly grey, and of blue, grey, or yellow shales, are exposed; but throughout all this thickness of beds, no fossil remains have been detected, except a few carbonaceous markings. Apparently at a somewhat higher horizon on the Mahton stream, which joins the Lhowa from the north, there is a great thickness of massive blue shales, of rather a dark indigo-blue in general, but sometimes of lighter colour. These shales cannot be much less than 3,000 feet in thickness; but they are almost as unfossiliferous as the sandstones and shales on the Lhowa, the only organic remains found being some cycloid fish-scales. Above these shales, again, there is a great thickness of sandstones and shales, mostly unfossiliferous, but containing a few layers with Nummulites; and at the top of the whole group is a band of nummulitic limestone, from 10 to 100 feet thick. This limestone, however, is by no means continuous: where it occurs, it seems to be the uppermost band of the group, but frequently it appears to thin out, and in fact to consist of irregular lenticular bands in shale, rather than of an unbroken bed. Denudation may, perhaps, also have removed the limestone in places before the deposition of the next group. Other bands of limestone occur at a lower horizon, but they are more irregular than that at the top of the group.

The whole thickness of the formation must be considerable—probably not less than 10,000 feet; but no estimate of any value can be made, on account of the imperfect manner in which the rocks are seen. In Northern Pegu, west of Thayetmyo, the breadth of the eocene outcrop from east to west is 17 miles; but a few miles to the south the width diminishes, till, west of Prome, it is not more than 6 miles. The

belt again expands in breadth near Thombo and Akouktoung, on the Irawadi, above Myanoung; but the beds in general are very poorly exposed, being covered with gravel and other late deposits. Farther to the southward, west of Myanoung and Henzada, the nummulitic rocks are much concealed by post-tertiary gravels; and from Henzada to Bassein the only rocks seen to the westward of the Irawadi plain are the altered Negrais beds. The nummulitic strata reappear west of Bassein, and continue thence to Cape Negrais; but still the rocks are much concealed by gravel. Throughout the area, however, limestone with nummulites occasionally appears amongst the higher beds of the group; and a peculiar, very fine, white or greenish, argillaceous sandstone, with *Foraminifera*, seen at Purian point, east of the Bassein river, and in Long Island on that river, is also probably one of the uppermost eocene beds. This rock, known as *Andagu-kyouk*, or image stone, is employed by the Burmese for carving into images of Buddha, and is quarried to some extent for that purpose.

It is possible that nummulitic beds may crop out in places amongst the miocene rocks of the Prome district; but the only known exposure of the former in Pegu, apart from the belt just noticed as extending along the eastern side of the Arakan Yoma, is in a small ridge, known as Thondoung, or lime hill, about 5 miles south of Thayetmyo. This ridge consists in great part of nummulitic limestone, resting upon shales and sandstones; and in the latter a promising bed of coal, 4 feet thick, was discovered in 1855, but proved so irregular as to be of no value; the coal thinning out, and passing into a clay with mere laminæ and patches of coaly matter, in the course of a few feet.[1]

Petroleum has been found in a few localities in Pegu within the older tertiary area; and it is probable that when mineral oil occurs in later tertiary beds, it has been derived from the underlying eocene strata. Such, at least, is Mr. Theobald's opinion after surveying the country, and it is in accordance with the geological distribution of petroleum in Assam.

Arakan.— To the west of the Arakan range, limestone with nummulites has been noticed near Keantali, a village on the coast, almost on the 18th parallel of north latitude; and there can be but little doubt that eocene beds extend along the coast for a considerable distance. The islands of Rámri and Cheduba consist of sandstones and shales closely resembling those of Arakan, and doubtless belonging to the same series.[2] These beds are also very similar to the nummulitic rocks of Pegu. A

[1] Oldham: Sel. Rec. Govt. India, Home Dept., No. X, p 99.
[2] Mallet: Rec. G. S. I., XI, p. 191.

few seams of coal have been found, resembling in character the nummulitic coal of Assam; and petroleum is obtained in several places. The limestone on the eastern side of Rámri Island, as already mentioned, resembles that of the Arakan coast near Mai-i and Tongúp, and may, therefore, be cretaceous; but there is no marked character by which the rocks of the island can be divided into two series.

Farther north the eocene beds probably continue, until they join those of Assam; but the intervening country is geologically unknown.

Coal-bearing rocks of Tenasserim.—Although nothing definite is known as to the age of the beds associated with coal in Tenasserim, except that they are in all probability tertiary, there is more likelihood that they belong to the older tertiaries than to the newer, because similar coal-bearing deposits in Assam on the one side, and Sumatra,[1] Java, and Borneo on the other, are known to be of eocene age. It will consequently be best to notice the Tenasserim beds in this place.[2] They have received more attention than the other rocks of Southern Burma, but still they are but imperfectly known.

The tertiary formations of Tenasserim consist of conglomerates, sandstones, soft shales, and beds of coal. The conglomerates are never coarse, the pebbles seldom exceeding a few inches in diameter; the sandstones are fine, gritty, and pebbly clean white quartzose sands, or earthy and of a yellowish tint; the shale beds are of a bluish-green or blackish tint, and very regularly disposed in thin laminæ. The coal is also in thin laminæ, with earthy bands.

These coal-bearing deposits, the total thickness of which nowhere exceeds 900 to 1,000 feet, are never traceable continuously over any extended area. They are found occupying isolated and detached basins in the great north and south valley of the Tenasserim river, between the main dividing range to the eastward separating British Burma from Siam, and the outer ridges to the westward near the sea-coast. The small tracts of tertiary rocks are in all probability of fresh-water origin, and have much the appearance of having been deposited in the small basins they now occupy. The only organic remains found are dicotyledonous leaves and scales and bones of fish.

The most important coal localities known are Thatay-khyoung and Heinlap on the great Tenasserim river, about 6 miles apart. At the former locality there is a workable coal-seam, 7 feet in thickness, including small partings of shale and clay; at the latter the seam is

[1] Geol. Mag., Dec. II, Vol. II, 1875, pp. 481, &c.

[2] This account is taken from Dr. Oldham's report: Sel. Rec. Govt. India, Home Dept., No. X, 1856, pp. 34–56.

between 17½ and 18 feet thick. The quality of the coal is fair, the proportion of volatile matter being large, but the percentage of ash is small. At Kaumapying, three-quarters of a mile north of Heinlap, there is a seam of about 8 feet in thickness, but containing much iron pyrites. Some coal also occurs on the Little Tenasserim river; but the only known seam is not more than three feet thick. The Lenya river coal, farther south, has already been shewn to be very possibly of cretaceous age.

Pegu group.—Above the nummulitic formation of Pegu, there is an immense thickness of soft shales and sandstones, often fossiliferous, but almost destitute of any horizon distinguished either by mineralogical characters or by organic remains. The base of this group is assumed to coincide with the band of nummulitic limestone, already mentioned; but there is no clear evidence that this bed is the uppermost rock of the eocene group, and no unconformity has been detected between the nummulitic rocks and the next strata in ascending order. The upper limit of the middle tertiary rocks of Pegu is equally ill defined, there being a gradual passage from clays and sandstones with marine fossils into the gravels and sands with silicified fossil-wood and mammalian bones.

The fact is that, without a thorough knowledge of the fossils, the classification of rocks so obscure and so ill seen as those of Pegu is a simple impossibility; and until the tertiary mollusks, echinoderms, and corals of Southern Asia are better known, it is hopeless to attempt more than a general rough arrangement of the Burmese tertiaries. In the absence of sufficient fossil data for the proper determination of different beds, all that has been attempted at present is to class together all the marine beds of Pegu without nummulites, and at a higher horizon than the nummulitic limestone; and the group thus constituted has been named the "Pegu group" from its forming the greater part of the Pegu Yoma between the Irawadi and Sittoung. There can be no doubt that a portion of this group is of miocene age, and corresponds generally to the Gáj group of Sind[1]; but it is probable that representatives of other formations are included.

The only approach to a sub-division of the Pegu group that has been suggested is the separation of a considerable thickness of soft unfossiliferous blue shales, which near Prome rest upon the upper nummulitic strata, and underlie the typical fossiliferous middle tertiary beds. These shales have been called the "Sitsyahn shales," from a village on the Irawadi, 8½ miles above Prome; whilst the overlying sandstones and shales with fossils are distinguished as "Prome beds," from their occurrence in

[1] See *ante*, p. 463.

the neighbourhood of Prome. The Sitsyahn shales consist of blue clunchy clay, with indistinct bedding, and, except that they are somewhat paler in colour, greatly resemble some of the nummulitic shales. The thickness of the sub-division is about 800 feet, and the beds have been traced for a considerable distance along the upper limit of the nummulitic rocks in the Prome district.

The Prome beds succeed the Sitsyahn shales conformably, and are composed of grey sandstones, occasionally hard, but frequently argillaceous or shaly, hard yellow sandstones, and shales or clays of various colours. A section of about 2,500 feet of these beds is seen opposite Prome on the right bank of the Irawadi, and probably a much greater thickness exists east of the river. One of the most fossiliferous beds is a band of blue clay exposed at Káma on the Irawadi, 18 miles above Prome. The position of this band is high, and, above it, a bed, abounding in *Turritellæ*, and a hard sandstone containing corals belonging to the genus *Cladocera*, are the highest rocks of the group, and mark the passage into the fossil-wood beds.

In one locality, Minet-toung (Myay-net-toung), 24 miles east-south-east of Thayetmyo, a bedded volcanic rock occurs, consisting of greyish trap, interstratified with the rocks of the Pegu group, and, to all appearance, contemporaneous. Nothing has been ascertained as to the source of this igneous formation.

It is almost useless to give any palæontological details. *Foraminifera* and *Echinodermata* are rare, and the mollusca are not, as a rule, very characteristic forms. A sessile cirriped, very common in some beds, closely resembles *Balanus sublævis* of the miocene in Sind. A few small crabs occur; small corals and sharks' teeth are common.

The Pegu group forms nearly the whole of the great range of hills, known as the Pegu Yoma, between the Irawadi and Sittoung, no older rocks being known with any certainty to occur in the country between the two rivers. The area occupied by the middle tertiary beds is very broad to the northward, where it extends from considerably west of the Irawadi to the base of the metamorphic hills east of the Sittoung, and contracts gradually between the alluvial plains of the two rivers to the southward, till it terminates in a long narrow spur at Rangoon. West of the Irawadi, the Pegu group extends to a little below Prome, and some hills on the opposite side of the river below Prome are formed of the same beds. It is, however, not quite certain that no older rocks appear between the Irawadi and Sittoung; for in some beds in Eastern Prome a species of *Pseudodiadema*, a genus of echinoderms with cretaceous affinities, has been found, and a *Terebratula* with a very cretaceous aspect

was obtained near the town of Pegu. In the former case the beds appear to be high in the Pegu group; but owing to the great extent to which the surface of the country is concealed, both by gravel and other alluvial deposits, and by forest, it is most difficult to make out the geology satisfactorily, and lower beds may be brought up to the surface by faults or otherwise. In the case near Pegu the position of the beds is uncertain.

Newer tertiary beds in Arakan.—On the Arakan coast, in latitude 16° 30′ 50″, is a small island known as Kaurangyi (Koranji), composed of calcareous sandstone or earthy limestone, of a very pale brown or cream colour, and containing echinoderms, mollusks, sharks' teeth, and other fossils. The same rock occurs also at Nga-tha-mu on the mainland opposite Kaurangyi Island, but has not been detected elsewhere. Amongst the fossils the most abundant are a species of *Lobophora* (*Echinodiscus*) and an *Echinolampas*, apparently *E. jacquemontii*, one of the commonest fossils of the Gáj group in Sind: the *Echinodiscus* also closely resembles a Gáj species. The bed is somewhat similar to the "miliolite" of Kattywar, and may represent a portion of the Pegu group; but it is perhaps more probably of later date. One of the sharks' teeth, however, closely resembles one found in the Pegu group south of Thayetmyo.

Pliocene fossil-wood group.—The highest member of the tertiary series in Pegu is distinguished by the abundance of silicified dicotyledonous wood, and is the source whence all the fragments of that substance, so abundant in the older and newer alluvial gravels of the Irawadi, are derived. The fossil-wood group is much coarser than the underlying formations, and consists of sands, gravels, and a few beds of clay or shale, all, as a rule, being soft and incoherent; although occasionally hard sandstone or conglomerate bands occur. The group is thus sub-divided:—

a. *Fossil-wood sands.*—Sand, in part gravelly and conglomeratic, characterised by a profusion of concretions of iron peroxide.

b. *Fine silty clay*, with a few small pebbles.

c. *Sands, shales*, and a few conglomerate beds, with a little concretionary iron peroxide.

The lowest bed *c* passes downwards into the marine bands of the Pegu group, and contains, sparingly, rolled fragments of silicified wood, and a few mammalian bones. Some sharks' teeth also occur. The thickness of none of these sub-divisions has been clearly ascertained; but the lower sands must comprise beds some hundreds of feet thick. The fine silty clay does not exceed about 40 feet in thickness. This bed is quite unfossiliferous, neither fossil-wood nor bones having been found

in it, and pebbles are rare, though a few occur. It thus forms a marked band in the group, and contrasts with the beds above and below it.

The upper fossil-wood sands and gravels are by far the most important members of the formation, and it is from them that the greater portion of the silicified wood is derived. This wood occurs in the form of large and small masses, some being trunks of trees 40 or 50 feet long; usually, however, such masses display marks of attrition, as if the tree stems before being silicified had been transported to a distance and rolled. The wood is always, or nearly always, exogenous; a few rolled fragments of endogenous wood found in newer formations being nevertheless, in all probability, originally derived from the present group. The wood is not coniferous; but owing to the very considerable amount of decomposition it had undergone previous to silicification, its nature is difficult to determine. Besides the fossil-wood, another characteristic of this portion of the group is the abundance of concretionary nodules of hydrated iron peroxide; these are in places so numerous as to have furnished a supply of iron-ore for the native furnaces. Mammalian bones are of only local occurrence.

The following is a list of the *Vertebrata*, exclusive of sharks' teeth, hitherto obtained in the Irawadi valley from the beds of the fossil-wood group :—

MAMMALIA.

Ursus, sp.	*Tapirus*, sp.
* *Elephas* (*Stegodon*) *cliftii.*	*Equus*, sp.
* *Mastodon latidens.*	*Hippopotamus* (*Hexaprotodon*) *iravadicus.*
* *M. sivalensis.*	* *Merycopotamus dissimilis.*
Rhinoceros iravadicus.	*Cervus*, sp.
R., sp.	*Vishnutherium iravadicum.*
* *Acerotherium perimense.*	*Bos*, sp.

REPTILIA.[1]

Crocodilus, sp.	*Emys*, sp.
Gharialis, sp.	*Trionyx*, sp.
Testudo, sp.	*Emyda*, sp.
* *Colossochelys atlas.*	

* Those marked with an asterisk are also found in the Siwaliks of the Sub-Himalayas.

It has been shewn[2] in the chapter on the Siwalik fauna that the mammaliferous beds of the Irawadi valley are of approximately the same age

[1] These genera are recorded amongst the Ava specimens in the collection of the Asiatic Society, Falconer, Cat. Fos. Rem. Vert. Mu . As. Soc., 1859, p. 30; but as all the specimens were unlabelled, there is some doubt about the locality.

[2] See *ante*, p. 588.

as the Siwaliks, or pliocene, if the views as to the relations of the Siwalik fauna advocated in the present work be accepted. Silicified wood abounds in places in some of the Siwalik beds of the Punjab and in the Manchhar beds of Sind; but in the Sub-Himalayan Siwaliks remains of trees are carbonised, not silicified, and there is no great mineralogical resemblance between the Siwaliks and the pliocene sands and gravels of Burma. Independently of the fact that the rocks supplying the materials from which the beds have been derived east and west of the Bay of Bengal are probably very distinct, there is some doubt as to the conditions under which the Burmese beds were deposited, owing to the frequent occurrence of sharks' teeth; and it has been suggested that the fossil-wood group may have been, in part at least, marine or estuarine. The silicified wood itself is never bored by xylophagous mollusca (*Teredinidæ or Pholadidæ*); and as in India, at the present day, not only all wood floating on the sea, but all found anywhere in tidal creeks, and even the dead trunks and branches of trees in places flooded by the tide, are riddled by boring mollusks, it is extremely improbable that the wood found in the Burmese pliocene beds can have been immersed for any length of time in salt water; whilst the tree-stems can scarcely have been silicified before being imbedded, as they would have been in that case too heavy to be transported. It is true that the beds containing sharks' teeth are not those in which the fossil-wood is most abundant; but still some fragments of wood occur with the teeth, and mammalian bones are common. The beds generally are much too coarse for estuarine deposits; and if they are marine, it is difficult to understand why no mollusks or echinoderms, &c., occur. On the whole, it is most probable that the fossil-wood beds, like the Siwaliks and Manchhars, are fluviatile or subaërial, deposited by streams and rainwash, and that the sharks inhabited rivers, as some species do at the present day.

But another distinction between the Burmese and Indian pliocene beds requires notice, as it indicates a wide difference in the later geological history of the two countries. The Siwaliks, as has been amply shewn in the chapters relating to the Sub-Himalayan rocks, have been greatly disturbed, turned on end, and compressed by a lateral thrust. The fossil-wood beds of Pegu and Upper Burma exhibit very slight disturbance, and are generally horizontal. It is thus evident that the great changes to which the Sub-Himalayan ranges, and probably a considerable proportion of the Himalayan elevation, are due, did not affect the Irawadi valley, or only affected it very slightly.

The fossil-wood beds in Pegu are evidently the mere remnants of a formation which once occupied a far more extensive area, the former

existence of the beds being shewn by the occurrence in abundance of fragments of silicified wood far beyond the present limits of the group. At present the only country within British territory where the beds still occupy a considerable area is in Northern Prome. These pliocene strata are rather extensively distributed east of the Irawadi, between Prome and the frontier; and some large patches still exist, although much denuded, on the west of the river, in the neighbourhood of Thayetmyo. Judging, however, from the occurrence of the larger blocks of fossil-wood alone, and neglecting the small fragments in the alluvial gravels, the beds of the present group formerly extended far to the southward, probably along the whole eastern side of the Arakan Yoma, and almost certainly as far as Rangoon along the Pegu range. A considerable area in the Sittoung valley, north of Tonghoo, is also occupied by the fossil-wood beds; but no traces of the former existence of this group is found south of the Kaboung stream, which joins the Sittoung from the westward a little below Tonghoo. There is rather more clay associated with the pliocene beds in the Sittoung than in the Irawadi valley; whilst in two small outlying patches, east and north of Tonghoo, the group is represented by a form of laterite containing numerous pebbles.

Tertiaries of Upper Burma.—The Irawadi valley, from the British frontier to the neighbourhood of Ava, where the metamorphic area is entered, consists of the same tertiary rocks as are traversed by the river in Pegu; but the newer beds with mammalian bones and fossil-wood occupy, comparatively, a much larger area than in Pegu. It is uncertain whether any true nummulitic rocks occur in the neighbourhood of the river, or whether all the fossiliferous clays, shales, &c., should be referred to the Pegu miocene group; but the latter is certainly well represented. From the pliocene gravels the majority of the mammalian remains hitherto collected in Burma have been obtained.

About 50 miles above Ava, the river again runs through tertiary rocks, in which, near Thingadau, some coal has been found. The quality is not very good, but some of the seams are from 3 to 5 feet thick. Nothing is known as to the extent of the coal-seams, nor have any fossils been found to shew the age of the beds; but they are probably eocene.

The most important petroleum wells in Burma are at Ye-nán-khyoung, 60 miles north of the British frontier. The age of the rocks has not been ascertained; they contain marine fossils, and probably belong to the Pegu group. The wells are situated on an anticlinal; all the rocks are very soft—too much so for any fissures to remain open in them—and the mineral oil is apparently derived from a porous stratum.

Extinct volcano of Puppa.—About 50 miles north-north-east of Ye-nán-khyoung, and 25 to 30 miles east-south-east of Pagán, both large towns on the Irawadi, the extinct volcano of Puppa[1] rises to a height of about 3,000 feet above the undulating country, composed of pliocene sands and gravels. The mountain has preserved its original form to some extent; but the crater has been greatly broken down by denudation, and the rim completely cut away at one point, where the drainage from the interior has made itself a means of exit. The peak consists of ash breccia; but lava-flows, mostly trachytic, form the lower slopes and the surface around the base of the volcano. Amongst these flows, some consist of a very beautiful porphyry, with crystals of pyroxene.

The horizontal beds of gravels and sands around the base of the volcano contain fossil-wood and ferruginous concretions, and belong apparently to the pliocene fossil-wood group. They are capped by the lava-flows, and contain pumice and volcanic fragments; and in one place a bed of ash breccia was found interstratified with them. It appears highly probable, therefore, that the volcano was active in pliocene times; but it may have continued to emit lava and scoriæ at a later period.

Far to the northward, in Yunnan, in latitude 25°, another extinct volcano has been observed near Momein.[2]

Trachyte in South-western Pegu.—About 4 miles east by north of the village of Byangyee on the Bassein river, 14 miles south of Nga-pu-tau, and 30 miles south of Bassein, a mass of trachyte occurs, about 6 feet in diameter, and known in the neighbourhood as "kyouk-ta-lon." The relations of this mass are obscure, but it may be part of an intrusive pipe vein: there is no reason to suppose that the block can have been transported from a distance. It is remarkable that the spot is only 15 miles east of a straight line from Barren Island, an active volcano in the Bay of Bengal, to Puppa. It is by no means improbable that the Momein volcanic outburst is connected with the same line of vents, and that it is on the prolongation of the great chain of volcanoes traversing the Malay Archipelago, or the Moluccan band of some writers; the idea, so commonly put forward in text-books, that the northern extremity of this volcanic line is to be found in Rámri and Cheduba, being due to a mistaken notion as to the nature of the mud volcanoes in those islands: the real character of the latter outbursts will be explained presently, after a brief notice of the post-tertiary and recent formations of Burma.

[1] J. A. S. B., XXXI, 1862, p. 215.

[2] Anderson: Report on the Expedition to Western Yunnan, pp. 90, 312.

Post-tertiary deposits: laterite.—Here and ther(n the edge of the alluvial tracts of the Irawadi and Sittoung river n Pegu and Martaban, laterite of the detrital low-level type is fou, forming, as usual, a cap to other rocks, and having a very low dip to rds the river from the sides of the valleys. The laterite appears to m the basement bed of the post-tertiary gravels and sands; and terite gravels, apparently derived from the denudation of the massive la rite, are largely dispersed through the older alluvial deposits.

A few patches only of laterite occur in the Myan ig district, west of the Irawadi; but the rock is more common along western foot of the Pegu Yoma. To the east of that range laterit generally wanting; but to the east of the Sittoung river there is a w marked belt of this formation along the base of the metamorphic hi The lateritic rock here forms a plateau, rising 50 or 60 feet above the m of the Sittoung valley. Some laterite is also found in Tenasseri whence it extends into the Malay Peninsula.

Older alluvial sands and gravels.—Along the ma of the Irawadi and Sittoung alluvium, there is a broad, but interru l, belt of undulating ground, clearly distinguished from the flat alluvi lains near the river, both by the greater inequality of its surface and its more sandy character. This tract is locally known as "Eng-c ," or the country of the Eng tree (*Dipterocarpus grandiflora*); but the ie name is naturally applied to the very similar sandy tracts occupied b ie pliocene fossil-wood group, so that the popular distinction does no ecisely coincide with the geological limits of the formation.

The Eng-dain tract is composed chiefly of gravel, derived i large measure from the neighbouring hills, but partly from a dista . A portion of the deposits, as on the edge of the Ganges valley,[1] ma mply be "bhábar," the detritus washed from the surface of the hills rain and small streams, and forming a slope at the base of the range; it in Pegu, as in other countries with a heavy rainfall, this slope is inc ider-able, and a great portion of the alluvial gravels are simply stre and river deposits. Similar beds of sand and gravel are found in nany places underlying the argillaceous delta deposits of the Irawadi, a are evidently of more ancient origin.

Besides the fringe, of variable width, formed by the gravels al the edge of the older rocks, large tracts of the same older alluvial depo s are found in places isolated in the delta, forming occasionally groun aised to a considerable height above the flat country around. One suc tract, about 20 miles long from north-east to south-west, by 10 miles b d,

[1] See *ante*, p. 403.

occurs east of Nga-pu-tau and south of Bassein; another, of about the same dimensions, lies south-west of Rangoon. These areas may be ancient bhángar deposits, or they may be caused by local upheaval.

Delta of Irawadi.—Except in the immediate vicinity of the river channel, there is no important expanse of alluvial deposits in the valleys of the Burmese rivers; the beds of all, immediately above their deltas, are formed in places by older rocks, and there is no such continuous alluvial plain as is found along the course of the Ganges and Indus. Small tracts of alluvium occur, as usual, every here and there; but the wide undulating plains in the neighbourhood of the river in Upper Burma are composed, not of river alluvium, but of the pliocene fossil-wood deposits.

Compared with the Gangetic and Indus deltas, those of the Irawadi and other Burmese rivers convey an idea of imperfection and backwardness, as though the latter were of more modern growth than the former, and had made less progress towards the formation of a great fertile plain. The Salwin cannot be said to have any delta at all; and in the Irawadi delta, as has already been mentioned, elevated tracts, both of rock and of the older alluvial deposits, occur in the neighbourhood of the sea. Considering the size of the river, the Sittoung delta, if the alluvial plain extending to the northward beyond Tonghoo be included, is proportionally more extensive than that of the Irawadi; but still the broad Gulf of Martaban extends into the very mouth of the Sittoung river.

The Irawadi delta[1] extends from the Rangoon river to the Bassein river, and the head of the delta may be placed near Myanoung.[2] The first important distributary—that forming the head of the Bassein river—leaves the main river a little above Henzada; but water overflows in floods some miles above Myanoung, and finds its way to the sea by the Myit-ma-kha Khyoung, the origin of the Rangoon river. The various rivers and creeks of the Irawadi delta are said to be far less liable to change than those of the Ganges and Indus; but it must be remembered that the authentic history of the latter rivers, and especially of the Indus, extends much farther back than does that of the Irawadi. The general surface of the delta near the sea, with the exception of the higher tracts already mentioned, differs but little in elevation from that

[1] Theobald: Rec. G. S. I., III, p. 21.

[2] Mr. Theobald considers Mengyi, 13 miles below Myanoung, the apex of the delta; and taking Purian Point, east of the Bassein river, and Elephant Point, west of the Rangoon river, as the two lateral angles, he estimates the distances from Mengyi to Elephant and Purian Points as 129 and 176 miles respectively, the two points being 137 miles apart. The area of the entire delta would thus be 8,766 miles.

of the great Indian rivers; and Mr. Theobald considers that at least 2,000 square miles must be below the level of high spring-tides. Large marshes or jhils ("*eng*," in Burmese) are found occupying the depressions between the raised banks of the principal streams; and the whole region, especially in the neighbourhood of the sea, consists of a network of tidal creeks. Little appears to be known as to the progress of the delta seaward: judging by the contour of the coast, it would appear that the Irawadi, owing to its far greater size, and perhaps to the larger proportion of silt transported by its waters, had pushed its delta seaward far beyond the Sittoung. The Salwin traverses for the most part an area of hard metamorphic rocks, and probably brings down but little detritus; so that the conversion of the Gulf of Martaban into land, if it is ever to be effected, must depend largely upon the deposits from the Irawadi.

The alluvial plain and delta of the Lower Irawadi consist mainly of a clay [1] very similar to that found in the Gangetic plain, but containing much less lime, and, in consequence, poor in kankar. The colour is generally yellowish-brown, sometimes reddish, owing to the presence of peroxide of iron. The proportion of sand varies, and is, on the whole, greater than in the Gangetic alluvium. A few thin layers of sand occur, interstratified with the clay; and a band of dark-blue or carbonaceous clay, a few inches in thickness, has been noticed in several localities.

The clay, in many places towards the head of the delta, is seen to rest upon pebbly sand, and the latter is frequently found beneath the clay in the delta itself; wells being sunk through the argillaceous surface formation to the porous stratum beneath. In the absence of any borings, however, it is impossible to say what the nature of the beds at a depth below the surface may be; and it is not clear whether the sand is the underlying formation throughout, or whether it is merely intercalated between beds of clay.

On the surface of the clay, in the immediate neighbourhood of the river, deposits of silt and sand are found in some places, and resemble the khádar deposits of the Ganges valley. No extensive area, however, is covered by these sandy beds; they form a narrow belt along the river channel above the influence of the tide, and occupy a rather larger area around Pantanau. The deposits of the Sittoung alluvial plain closely resemble those of the Irawadi.

[1] Mr. Theobald considers this clay marine or estuarine, but no fossils have been found in it; and his main arguments, founded on the similarity between the clays of the Irawadi and Gangetic deltas, are of course favourable to the fluviatile origin of the Irawadi clay, if that of the Ganges be also, as has already been contended (*ante*, p. 393), of fresh-water origin.

Littoral concrete of Arakan coast.—In many places on the Arakan coast, and especially along the course of several of the less sheltered tidal creeks, a more or less compact calcareous sandstone, containing shells and corals of recent species, is found at some elevation above the level of the highest tides. The rock is porous, evidently formed by the cementation of shells, sand, &c., by carbonate of lime; and precisely similar to the littoral concrete of Bombay, Kattywar, &c. As in Western India also, the presence of this calcareous rock on the Arakan coast affords evidence of a rise of land within a geologically recent period.

On the shores of Rámri and Cheduba, the evidence of elevation is very marked, and some details of the amount and date of the latest movements have been recorded.[1] By these accounts it is shewn that the last rise of the land took place about 1760, and varied in amount from 9 to 22 feet, being greatest in the north of Cheduba, and less to the south-east and north-west.

A few sand dunes are found on the Arakan coast, but they are small and unimportant.

Mud volcanoes of Ramri, &c.—The peculiar geological phenomena presented by the so-called "mud volcanoes" of Arakan and Burma deserve a passing notice. The best known vents are those of Membu[2] (Menbo or Memboo) on the Irawadi, 42 miles north of the British frontier, and those of the islands of Rámri and Cheduba on the Arakan coast; a few others are reported, but they are small and isolated, and consist only of temporary outbursts.[3]

The Rámri mud volcanoes are more interesting than the others, since they alone, so far as is known, are subject to paroxysmal eruptions of great violence, and from them alone stones have been ejected and flames emitted. Some of the principal phenomema may be briefly described here. There are about a dozen or rather more vents in Rámri Island itself, more than half that number in Cheduba, and a few in the other

[1] Halsted: J. A. S. B., X, 1841, p. 434; see also Mallet: Rec. G. S. I., XI, p. 190; and Map of Arakan Islands.

[2] For a description of the mud volcanoes of Membu by Dr. Oldham, see Yule's "Narrative of the Mission to the Court of Ava in 1855," p. 339. The Rámri and Cheduba mud volcanoes are described, with full references to earlier accounts, by Mr. Mallet: Rec. G. S. I., XI, p. 188. Figures of the cones are given in both cases. Mr. Mallet's paper was published after page 379 of the present work was printed; hence the omission of a reference.

[3] No "mud volcanoes" are found in the Indian Peninsula or in the Himalayas; but there is one in Assam, and there are some on the Baluchistan coast, west of the British frontier. See for descriptions, Trans. Bom. Geog. Soc., IX, p. cviii; X, p. 154; Stiffe: Q. J. G. S., 1874, p. 50. The details differ in no respect from those of the Rámri vents.

neighbouring islands. Near Kyouk-phyu (Kyauk or Kyouk-phyoo) in Rámri, six occur in a line, within a distance of about a mile and a half, along the summit of a low broad ridge.

Many of the vents consist of truncated cones, built up of the dried mud ejected by outbursts of gas. The crater, filled with mud, more or less liquid or viscid, through which the gas escapes, occupies the top of the conical hillock. The majority, however, of the Rámri "mud volcanoes" consist of mounds composed, on the surface, of angular fragments of rock, and having scattered over them a few small mud cones of trifling height (from a few inches to 8 or 10 feet), with craters at the top. When gas ceases to be emitted from a vent, the mud is rapidly washed away by rain, and a low mound remains, composed of angular fragments of rock, ejected together with the mud; and a similar process accounts for the formation of the mounds. The mounds in Rámri are from 50 to 100 yards in diameter, with a height of from 15 to 30 feet; two of exceptional size, in Cheduba, near Pagoda hill, being 200 and 250 yards across. The cones in which the mud is viscid are very steep, being built up partly of small quantities of mud spurted out by the evolution of gas, so as to form a hard rim round the mud crater, partly of mud poured out from the crater down the slopes through broken portions of the rim.

Besides the gas and mud, a small quantity of petroleum is usually discharged from the vents. The gas consists mainly of marsh gas (light carburetted hydrogen), mixed probably with some of the more volatile hydrocarbons usually associated with petroleum. The mud is simply the grey shale or clay of the tertiary rocks, mixed with water, containing some salt in solution. There is not the slightest connexion with any real volcanic action; no igneous rocks are found, and if some few stones appear to have been subjected to heat, this is due to the occasional ignition of the inflammable gases emitted. The only distinction between "mud volcanoes" and ordinary emissions of marsh gas is, that in the former case the gas traverses a bed capable of being easily mixed with water, so as to form mud; and this, like the water and petroleum, is carried to the surface by the gas. The term "volcano" applied to such phenomena conveys a false idea of the nature of the action.

The association of petroleum with large quantities of marsh gas, and the frequent emission of water, usually saline, and of gas in abundance, from borings for mineral oil, are too well known to require the recapitulation of details. Both the petroleum and the gas are produced during the slow change of woody fibre into lignite and coal, and both products are known to be found in many localities amongst the tertiary

rocks of Extra-Peninsular India and Burma. Not unfrequently both gas and mineral oil issue with water, in the form of a bubbling spring; both water and petroleum being, perhaps, forced to the surface by the pressure of the gas. Whether a spring of this kind forms a "mud volcano" or not, depends evidently on the nature of the beds traversed on the way to the surface. As a rule, the mud in these vents is either of the same temperature as the air, or a little higher; but in the Rámri craters a higher temperature has been recorded after the more violent eruptions.

These paroxysmal eruptions appear to occur at irregular intervals, and are at times very violent; they appear frequently, perhaps usually, to accompany earthquakes; mud and stones are shot out with great force, accompanied by large quantities of inflammable gas, which in many cases takes fire, and lights up the country for miles around. Some of these eruptions of ignited gas have taken place at sea off the coast of Rámri; and in one case a small island was formed near False Island, south of Rámri and south-east of Cheduba; but it was soon washed away again. The ejected stones are in all cases fragments of the tertiary rocks, chiefly shale or sandstone, some of them being from half a cubic foot to a cubic foot in size, and a few larger; but the majority are from half an inch to 5 or 6 inches in diameter. The ignition of the gas is ascribed by Mr. Mallet to frictional electricity,[1] and not to the high temperature at which the various ejecta issue; the fact that the stones and even fragments of lignite thrown out during eruptions are, as a rule, entirely unchanged by heat, proving that the gas is not in a heated state previous to emission. A very few fragments of burnt and reddened shale have been found, and these have probably been calcined by the flaming gas; but they are rare and exceptional.

It should be noticed that even the fiery eruptions of the "mud volcanoes" of Arakan have nothing in common with the igneous outbursts of true volcanoes. In the former, gas emitted at, in all probability, a low temperature, is ignited, or perhaps occasionally exploded, when mixed with atmospheric air, and flame ensues; in the latter red-hot lava and scoriæ are ejected, and the appearance of flame is due either to the high temperature of the substances projected into the air, or to the reflection of masses of flowing lava by condensed vapours or by clouds of volcanic dust.

[1] *l. c.*, p. 202. Mr. Mallet points out that the principle of the hydro-electric machine, in which the production of electricity of high tension is due to the issue of partially condensed steam through small orifices of such form as to produce great friction, is similar to that of violent evolution of gas from such vents as these of Ramri. He also notices the well-known fact that lightning often accompanies volcanic eruptions.

Islands in the Bay of Bengal.—Of the islands in the Bay of Bengal, exclusive of those forming the Mergui Archipelago, which consist of detached fragments of the Tenasserim rocks, and of the geology of which but little is known, the only groups requiring notice are the Andamans and Nicobars, Narcondam and Barren Island.

The Andamans, and probably the Nicobars, are a continuation of the Arakan Yoma, the islands of Preparis and the Cocos being parts of the same line of elevation, and serving to connect the northernmost of the Andaman group with Cape Negrais. The idea expressed in some geological works, that the continuation of the line of summits formed by the Nicobars and Andamans is to be traced in the islands of Cheduba and Rámri, is not quite accurate, as may be seen by examining a good map. To the southward, the same line of elevation may, perhaps, be continued in Sumatra and Java, as the rocks of all these islands present some points of similarity; but no trace of the volcanic band, so conspicuously developed in Java and Sumatra, is known to exist in the Nicobars or Andamans; and the northern extremity of the great series of igneous vents which traverses the Malay Peninsula may probably be found, as already noted, in Barren Island and Narcondam, and perhaps still farther north, in the extinct volcanoes of Upper Burma and Yunnan.

Andaman Islands.—Although there has been a large convict settlement on the Andamans for nearly twenty years, and although the islands have repeatedly been visited by geologists, very little is known of the rocks, except in the neighbourhood of Port Blair, the British station. The islands are for the most part covered with dense, almost impenetrable, forest, and the coasts, owing to coral reefs and rocks, are difficult of access. The only geological information of any importance hitherto published is contained in Mr. S. Kurz's "Report on the Vegetation of the Andaman Islands,"[1] and in a few details given by Mr. Ball[2] of the neighbourhood of Port Blair.

The Archipelago consists of Great Andaman, comprising North, Middle, and South Andaman, and Rutland Island, all separated from each other by narrow straits or inlets; Little Andaman, about 35 miles south of Rutland Island, and numerous small islets. The larger islands are hilly, and consist of ranges having a general direction from north by east to south by west, parallel to the longer diameter of the group and to the line running from the North Andaman, through the Cocos and Preparis, to Cape Negrais. The highest elevation, Saddle Mountain, in North

[1] Published in 1870. A Geological map is given, shewing the nature of the rocks in all places visited by Mr. Kurz.

[2] J. A. S. B., 1870, XXXIX, Pt. 2, p. 231.

Andaman, rises to rather more than 3,000 feet above the sea; Ford Peak on Rutland Island may exceed 2,000; but most of the ridges are lower. Nothing is known of the geology of North Andaman, nor of Little Andaman; but they in all probability consist of the same rocks as the other islands.

The formations of Middle and South Andaman are extremely similar in appearance to the Negrais rocks of the Arakan Yoma, and in all probability belong to the same group. The prevailing rock is sandstone, fine-grained, grey or greenish in colour, and often containing shales intercalated. Traces of coal occur, chiefly in nests, no true seam having been detected.

An indurated chloritic rock of a dark-green colour, rather felspathic, intersected by small veins of quartz and calcite, and containing crystals of quartz and other minerals in small cavities, extends for a considerable distance northwards from Port Blair, and probably the same band reappears in the Middle Andaman. This bed has the appearance of being a greatly altered form of sandstone, and is precisely similar to one of the rocks occurring in the Arakan Yoma. Serpentine and gabbro are found largely developed south of Port Blair and on Rutland Island, and are doubtless intrusive. A "micro-crystalline syenite" was noticed in one locality by Mr. Kurz; it is doubtless a form of the dioritic rock found locally associated with the serpentine in Pegu.

Unlike the Arakan coast and the Nicobar Islands, the Andamans appear recently to have undergone depression.[1] Stumps of dead trees are found in several places in the sea; and although some of these trees grow in the mangrove swamps, others belong to species which grow above the limit of high tides. There are also some records of encroachment by the sea on the coast, since the period of attempts at settlement in the islands towards the end of the last century; but these changes might be due to marine denudation. The evidence afforded by the tree-stumps appears, however, indisputable, and it shews that the movement of sinking must be very recent. No raised coral reefs have been detected, although some bands of conglomerate on the western side of the islands may indicate local elevation; but, on the other hand, the existence in abundance of kitchen-middens,[2] just where they might be expected to occur, close to the coast, appears to indicate that the sinking has been local, or else that the late movement of depression is exceptional.

[1] Kurz: *l. c.*, p. 4.

[2] Stoliczka: Proc. A. S. B., 1870, p. 13.

Nicobar Islands.—The geology of the Nicobars has been described by Danish and Austrian observers, members of the Galathea and Novara Expeditions.[1] The interior of the larger islands has never been examined; but, from observations made on the coast, a fair idea of the general geology has been obtained. There is a vague report of the existence of an active volcano in Great Nicobar, but no traces of recent igneous rocks have been discovered on the island; and although Hochstetter remarks that the highest peak of Great Nicobar has the form of a volcano, he is disinclined to believe that the mountain is really of volcanic origin.

The rocks of the Nicobar Islands, so far as they are known, comprise the following formations:—

1. Recent coral reef formations.
2. Marine deposits, consisting of sandstone, shales and clay.[2]
3. Serpentine and gabbro (intrusive).

Rink considers that there are sedimentary deposits of two ages, exclusive of the raised coral reefs; and he calls the newer "older alluvium," and the older "brown coal formation." The former comprises some argillaceous formations in the northern islands; the latter the sandstones and shales of which the southern islands are chiefly composed. Hochstetter classes all together, and is inclined to refer the whole to the newer tertiaries, and probably to upper miocene.

This view cannot, however, be accepted as conclusive in the case of the sandstones and shales. Ball[3] has pointed out the similarity of these beds to those of the Andamans, where the rocks are in all probability older tertiary or cretaceous; and the association of serpentine and gabbro is a character common to the rocks of the Nicobars, the Andamans, and Arakan. The principal tertiary formations of Sumatra also are known to be of eocene age; and it is highly probable that similar rocks to those of the Sumatran mountains occur in the Nicobar Islands, as the latter appear to be merely a prolongation of the former. With the exception of a few obscure vegetable organisms, no fossils have been found in the Nicobar sandstones and shales.

[1] Rink, Die Nicobarischen Inseln; Kopenhagen 1847: Hochstetter, Reise der Novara; Geologischer Theil, II, pp. 83-112; Vienna, 1866. A translation of the latter by Dr. Stoliczka was printed in the Records of the Geological Survey of India, II, p. 59. The geology of the neighbourhood of Nancowry harbour has also been described by Mr. Ball: J. A. S. B., 1870, XXXIX, Pt. 2, p. 25.

[2] In Rec. G. S. I., II, pp. 64, 65, &c., the German term "mergel" is translated clay-marls. This is incorrect, as the beds in question are free from lime: see Ball, J. A. S. B., 1870, Pt. 2, p. 27.

[3] *l. c.*, p. 27.

If, however, the sandstones and shales of the Southern Nicobars be older tertiary, it is far from improbable that Rink was right in separating the whitish yellow clays of Camorta, Nancowry, and others of the northern islands of the group; and the newer age of these clays is supported by the occurrence in them of detrital serpentine and gabbro fragments; for these igneous rocks are shewn to be of later date than the sandstones and shales, by being intrusive in the latter. At the same time the clays in question are, locally, much disturbed.

The whitish clays of Camorta and Nancowry collected by Rink were found by Ehrenberg to contain *Polycistina* in great abundance, no less than 300 species having been identified from Camorta alone.[1] The species are nearly the same as those composing similar clays in Barbadoes in the West Indies, and are considered as probably of miocene age.

The serpentine appears to be much more largely replaced by gabbro than in the Arakan Yoma, diallage and bronzite being of very common occurrence. These intrusive rocks break through the shales and sandstones, but fragments are associated with the *Polycistina* clays; and consequently the period of the serpentine eruptions, although posterior to the former, was prior to the latter. Serpentine and gabbro are chiefly developed in the northern islands, Teressa, Bompoka, Camorta, and Nancowry; whilst Tillanchang is almost entirely composed of these rocks.

The upraised coral reefs are found on the coasts of all the islands in places; they form a raised flat fringe, a few feet above the sea, and are covered by a forest of cocoanut palms. On Car Nicobar, Bompoka, and several other islands, these coral banks are of great thickness, and are raised 30 or 40 feet above the sea. The formation is clearly the same as the "littoral concrete" of Arakan and Western India, but richer in corals; and the same conclusions as to a recent rise of land are to be drawn from the occurrence of this fringe of sub-recent marine beds. A large collection of *Foraminifera* was made from the raised coral reefs of Car Nicobar by Prof. v. Hochstetter, and described by Dr. Conrad Schwager.[2]

Barren Island and Narcondam.—The last of the Bay of Bengal islands requiring notice differ entirely from all the others, by being, the one certainly, the other in all probability, recent or sub-recent volcanoes.[3] Barren Island has been repeatedly described by various visitors; Narcon-

[1] Monatshefte K. Akad. Wiss., Berlin, 1850. p. 476; Abh. K. Akad. Wiss., Berlin, 1875, p. 116. Numerous recent and sub-recent fresh-water infusoria from the Nicobars are described in the same author's "Microgeologie."

[2] Reise der Novara, Geol. Theil, II, pp. 187–268.

[3] For an account of these two islands, with full references to former descriptions, see Ball, Rec. G. S. I., VI, pp. 81–90.

dam has never been properly examined, and no one appears to have recorded an ascent to the peak.

Barren Island is about $1\frac{3}{4}$ miles in diameter, and nearly 6 miles in circumference, the highest peak being about 1,000 feet above the sea. The island rises from deep water. A high encircling ridge, broken down nearly to the sea-level on the north-west-by-west side, surrounds a central hollow, in the middle of which a cone rises to a height of 950 feet, with a small crater at the top. The whole consists of basaltic lava and ashes, the encircling rim being doubtless the remains of the original cone, after a large portion had been blown off by a violent eruption. The statement in many geological works, that the sea enters the inner basin, within the encircling rim, appears to be due to a misunderstanding of the original description.

This volcano was very active at the close of the last and beginning of the present century; of late years it is not certain that any eruptions have been recorded.

Narcondam, like Barren Island, rises abruptly from the deep sea to a height of about 1,300 feet. In consists of a tolerably regular cone, somewhat truncated at the top, where it forms three small peaks. The rocks on the beach consist of a conglomerate containing boulders of trachytic porphyry. The island is encircled by dense forest, which it was found impracticable to penetrate in the only recorded visit made by geologists. There can be no reasonable doubt that the island is a volcano; but no eruptions have been recorded, and the igneous action to which the peak is due may be extinct.

GLOSSARY.

ACICULAR: (*acicula*, a little needle). Needle-like, long and fine; a term applied to crystals.

ACROGEN: (ἄκρος, summit; γίγνομαι, I am formed). A subdivision of cryptogamic plants, comprising *Equisetaceæ*, ferns, mosses, &c.

ACTINOLITE: (ἀκτίς, a ray; λίθος, a stone). A variety of hornblende or amphibole, usually of a green colour, and frequently translucent; it occurs in long acicular crystals, and is often found in metamorphic rocks.

ACTINOZOA: (ἀκτίς, a ray; ζῶον, animal). A class of *Cœlenterata*, called also *Anthozoa*.

AGATE: (derivation said to be from the river Achates in Sicily). A variegated form of silica, banded with different colours, or with opaque and translucent layers alternating. It is commonly found lining cavities in basalt and other volcanic rocks.

ALBITE: (*albus*, white). A kind of felspar, usually of a white or grey colour, and differing from orthoclase or common felspar in containing soda instead of potash, and in crystallizing in the triclinic or anorthic system.

ALGÆ: (*alga*, seaweed). A class of cryptogamic plants, comprising various aquatic forms, such as seaweeds, and also very many low types, such as *Confervæ* and *Diatomaceæ*.

ALLUVIUM: (*alluo*, I wash against). Clay, silt, sand, and gravel deposited from water. The term is usually restricted to deposits from rivers, lakes, and seas, still existing, or which existed in very late geological times; and it is especially applied to the deposits formed by rivers when overflowing their banks.

ALUM: (*alumen*). A hydrous double sulphate of alumina and of an alkali. Common alum contains potash.

ALUMINA: An earth: the sesquioxide of the metal aluminium, containing two equivalents of the metal and three of oxygen. Alumina combined with silica is the basis of all clays.

AMETHYST: (ἀμέθυστος). Quartz or rock crystal, of a pink or purple colour, the colour being due to the presence of manganese or iron.

...ct genus of tetrabranchiate cephalopod mollusca, cham-...n, and coiled in a plane spiral. The shell is distinguish-...d of the still-surviving genus *Nautilus* by the sutures ... much curved and crenulated, and by the siphuncle being ...dorsal or external. By many modern palæontologists the genus has been divided into several. Ammonites range from carboniferous to cretaceous, and are especially characteristic of ...tral ...ith mesozoic strata.

AMORPHOUS, ...: (α, privative, and μορφή, form). A term applied to such min... ...argal substances as present no appearance of crystallization.

AMPHIBIA: (ἀμφί, bot... and βίος, life). A class of vertebrate animals, comprising the living ... frogs, newts, and salamanders, and the extinct *Labyrinthodonta*. By some na... ...uralists these forms are classed with reptiles, but the two differ grea... ... in embryonic characters, and in the fact that all amphibia breathe with gil... ... life, whereas reptiles breathe with lungs throughout.

AMPHIBOLE: (ἀμφίβολος, ambiguous; the mineral having been confounded with tourmaline). See "*Hornblende.*"

AMYGDALOID: (ἀμύγδαλον, almond; εἶδος, form). A volcanic rock containing small nodules of quartz, felspar, zeolite, or some other mineral. These minerals have been deposited in cavities which were originally, in most cases, air-bubbles in the molten rock.

ANALCIME: (ἄναλκις, weak; in allusion to its weak electric power when rubbed). A zeolite, composed chiefly of silica, alumina, and soda, and crystallizing in the cubical or monometric system. The ordinary form is a trapezohedron.

ANAMESITE: (ἀνάμεσος, intermediate). A fine-grained variety of dolerite or basalt, in which the constituent minerals are so minutely crystallized, that the rock appears homogeneous, except under the microscope.

ANASTOMOZE: (ἀναστόμωσις, inosculation). To open into each other. A term applied to the veins of leaves when they unite to form a network.

ANGIOSPERMS: (ἀγγεῖον, a vessel; σπέρμα, seed). The great subdivision of dicotyledonous phanerogamic or flowering plants, with their seeds encased. All ordinary dicotyledonous plants, except cycads, conifers, and *Gnetaceæ* are angiospermous.

ANNELIDA: (*annellus*, a little ring). Annelids, a class of *Annulosa* or *Articulata*, comprising worms, *Serpulæ*, &c.

ANNULOSA: (*annulus*, a ring). A primary division or subkingdom of animals, comprising worms, crustaceans, insects, &c., and corresponding to the Cuvierian *Articulata*.

ANORTHIC: (αν, negative; ὀρθός, straight). A system of crystals distinguished by having the three axes unequal and all obliquely inclined to each other.

ANTHOZOA: (ἄνθος, a flower; ζῶον, an animal). A class of *Cœlenterata*, called also *Actinozoa*, comprising the coral-animals, sea-anemones, and some other forms.

ANTHRACITE: (ἄνθραξ, carbon). Coal, deprived of most of its volatile ingredients, and consisting almost wholly of carbon.

ANTICLINAL: (ἀντί, opposite, and κλίνω, I incline). The curvature of strata in a ridge-like form, the convexity or salient angle being upward.

ANTICLINAL AXIS. A line drawn along the summit ridge of an anticlinal curve.

APATITE: (ἀπατάω, I deceive: the name was given from the resemblance to other minerals). Mineral phosphate of lime, crystallizing in the hexagonal system.

APOPHYLLITE: (ἀποφυλλίζω, I exfoliate). A hydrous silicate of lime and potash, with some fluorine; allied to the zeolites, and occurring in the same manner as zeolites in volcanic rocks. It crystallizes in the tetragonal or pyramidal system.

AQUEOUS ROCKS: (*aqua*, water). Rocks deposited by water, in contradistinction to igneous rocks, the formation of which has been due to heat.

ARENACEOUS: (*arena*, sand). Sandy or composed of sand.

ARGILLACEOUS: (*argilla*, clay). Composed of clay, or containing a large proportion of it.

ARKOSE. A detrital rock, composed of the materials of granite, quartz, felspar, and mica, and consisting frequently of angular fragments of those minerals in a sandy or argillaceous matrix.

ARTHROPODA: (ἄρθρον, a joint; πούς, a foot). Those classes of *Annulosa* which have jointed limbs: spiders, insects, myriapods, and crustaceans.

ARTICULATA: (*articulus*, diminutive of *artus*, a joint). Cuvier's name for the great animal subkingdom comprising worms, insects, crustacea, &c., now classed generally as *Annulosa*, or subdivided into *Annelida* and *Arthropoda*.

ARTIODACTYLA: (ἄρτιος, even; δάκτυλος, a finger or toe). A subdivision of the ungulate or hoofed mammals, having the toes of the feet either two or four in number. This group comprises the ruminants and some of the pachyderms of Cuvier, such as the pig.

ASCIDIOIDA: (ἀσκός, a bag; εἶδος, form). A class of *Molluscoida*, also known as *Tunicata*.

ASH, VOLCANIC. A general name applied to fragments of rock and dust (lapillæ, scoriæ, &c.) ejected from volcanoes. When consolidated, the mass forms a breccia, consisting of larger and smaller masses of various igneous rocks, such as basalt or trachyte, in a finer matrix.

ATOL: (a Malay word). A coral island consisting of a more or less perfect ring of coral rock surrounding a lagoon. The Maldive and Laccadive islands consist of atols.

AUGITE: (αὐγή, lustre). A mineral known also as pyroxene; one of the principal constituents of lavas, and especially of dolerite. It is composed of silica combined with lime, magnesia, iron, and other bases in varying proportions. Augite differs but little in composition from hornblende, and both crystallize in the same system, the oblique or monoclinic, but the angles differ.

AVES: (Latin for birds). Birds: one of the classes of the animal sub-kingdom of *Vertebrata*.

AZOIC: (α, privative; ζωή, life). A term applied to the oldest rocks, in which no organic remains have hitherto been discovered. See p. 37.

BACKWATER. A name applied to expanses of salt water close to the coast, and separated from the sea by sand-spits.

BASALT: (*basaltes*, Gr. and Lat.) An igneous rock, composed of augite and labradorite, often with olivine in disseminated grains. The term is chiefly applied to the hard, black, crystalline form of dolerite, and especially to that variety of the rock which exhibits prismatic structure.

BASIN. A defined area composed of strata, dipping in a concave form from the circumference towards the interior.

BASSET or BASSET EDGE. A miner's term for the outcrop of a bed.

BATHYMETRICAL: (βάθος, depth; μέτρον, measure). Distribution according to depth in the sea.

BATRACHIA: (βάτραχος, a frog). The *Anura* or tail-less *Amphibia*, including frogs and toads.

BED. A single definite layer of a sedimentary rock, irrespective of thickness.

BELEMNITE: (βέλεμνον, a dart). An extinct genus of dibranchiate *Cephalopoda*, having a straight, subcylindrical internal shell of great strength, solid and pointed at one end, and expanded so as to form a conical chambered area, known as the phragmocone, at the other. Belemnites abound in mesozoic rocks, especially in middle secondary or jurassic strata.

BERYL: (βήρυλλος). A mineral composed of silicate of alumina and glucina, crystallizing in the hexagonal system, and usually occurring in hexagonal pyramids. Emerald is a finely coloured and transparent variety of this mineral.

BHÁBER: (Hindi). See p. 403.

BHÁNGAR: (Hindi). See p. 404.

BHIL: (Bengali) = jhil: a marsh. See p. 406.

BIOTITE: (named after M. Biot). Uniaxial or magnesian mica; a silicate of alumina, iron, and magnesia, crystallizing in the hexagonal system, and usually dark-green or black in colour.

BOTRYOIDAL: (βότρυς, a bunch of grapes; εἶδος, form). Minerals and rocks are thus termed when, owing to concretionary structure, the surface is raised into numerous convex projections, resembling grapes.

BOULDER. A mass of transported rock, too large to be classed as a pebble.

BRACHIOPODA: (βραχίων, the arm; πούς, foot). A class of bivalve shells, placed by some naturalists with true mollusca, but by most modern systematists in the *Molluscoida*, with *Bryozoa* and *Tunicata* or *Ascidioida*. The *Brachiopoda* may be distinguished from true bivalve mollusca or *Lamellibranchiata* by their bilateral symmetry, by the structure of the hinge and texture of the shell, and, in many cases, by having one valve larger than the other.

BRECCIA: (Italian). A rock composed of angular fragments cemented together.

BRONZITE. A mineral allied to pyroxene, consisting of silicate of magnesia, with a variable proportion of iron, having frequently a bronze colour and lustre, and often associated with serpentine. Called also *Enstatite*.

BROWN-COAL. Lignite of a brown colour, found in tertiary rocks, and so abundant in certain miocene beds in Germany, as to have been furnished a name used by many geologists for a particular epoch.

BRYOZOA: (βρύον, moss; ζῷον, an animal). A class of compound aquatic animals, called also *Polyzoa*, forming a coating of cells on sea-weed, shells, rocks, &c., or else branched aggregates (corallines). One of the best known forms is the sea-mat or *Flustra*. The *Bryozoa* were formerly classed with the *Radiata*, and subsequently with *Mollusca*; but by most modern systematists they are placed in the *Molluscoida* with *Brachiopoda*, to which they are nearly allied in structure.

BUNTER: (German; variegated). The name applied to a subdivision of the Trias formation in Germany, on account of the prevalence of variegated sandstones. The term is now used for a group of the new red sandstone, in England and elsewhere, equivalent to the German Bunter.

CÆNOZOIC or CENOZOIC: (καινός, recent; ζωή, life). The latest great subdivision of geological time. The name has been applied by some geologists, in preference to tertiary, in order to preserve uniformity of nomenclature, and to introduce a term corresponding to mesozoic and palæozoic.

CALCAIRE GROSSIER: (Fr., coarse limestone). The name of an important subdivision of the French eocene tertiary beds.

CALCAREOUS: (*calx*, lime). Composed of lime, or containing a considerable quantity of it.

CALCITE: (*calx*, lime). Mineral carbonate of lime, crystallizing in the hexagonal system.

CAMBRIAN. A subdivision of palæozoic rocks, inferior to the silurian. The name is derived from Cambria or Wales.

CARBONIFEROUS: (*carbo*, coal; *fero*, I bear). A subdivision of upper palæozoic rocks, resting upon the devonian, and beneath the permian. The name is derived from the circumstance that all the most important coal beds of Western Europe belong to the formation.

CARNIVORA: (*caro*, flesh; *voro*, I devour). An order of mammalia, comprising cats, dogs, weasels, civets, bears, seals, &c.

CATACLYSM: (κατακλυσμός, inundation). A violent flood or deluge.

CENOMANIAN: (from *Cenomanum*, the Latin name for the town of Mans). A group of the cretaceous system, nearly corresponding to the upper greensand of English geologists.

CEPHALOPODA: (κεφαλή, head; πούς, foot). A class of mollusks, comprising cuttle fish, argonauts, *Nautili*, *Ammonites*, *Belemnites*, &c.

CETACEA: (κῆτος, a whale). An order of mammalia comprising whales and porpoises.

CERATITES: (κέρας, a horn). A genus of *Cephalopoda*, nearly allied to *Ammonites*, but distinguished by a more simple form of suture. The distinction, however, is now known to be less important than was formerly supposed. The genus is almost peculiar to triassic strata, though species have been found in carboniferous beds in India.

CERUSITE: (*cerussa*, white lead). Mineral carbonate of lead.

CHABASITE: (χαβάζιος, a kind of stone). A zeolitic mineral, a hydrated silicate of alumina, lime and soda with a little potash, crystallizing in the rhombohedral system, and generally occurring in basalt.

CHALCEDONY or CALCEDONY: (derived from the town of Chalcedon). A variety of uncrystallized silica, with a waxy lustre, and either transparent or translucent.

CHALCOPYRITE: (χαλκός, brass; πυρίτης, pyrites). Copper pyrites, sulphide of copper and iron, crystallizing in the pyramidal system.

CHALK. A soft white limestone. A rock of this kind, belonging to the upper cretaceous period, is largely developed in England and France, and has furnished the name used for the period.

CHAR: (Hindi; frequently written *chur*). A sandbank in a river. The term is applied to the banks of sand and silt left dry on the subsidence of rivers after the flood season, and frequently cultivated during the dry weather.

CHERT. Impure silica, or flinty portions of rocks.

CHIROPTERA: (χείρ, hand; πτερόν, wing). An order of mammalia comprising the bats.

CHLORITE: (χλωρός, green). A hydrated silicate of alumina, iron and magnesia, resembling mica, but of a green colour and very soft, occurring chiefly in scales and small crystals in metamorphic rocks.

CHONDRODITE : (χόνδρος, grain). A silicate of magnesia, with part of the oxygen replaced by fluorine, occurring usually as yellow or brown grains in crystalline limestone.

CHRYSOLITE : (χρυσός, gold). A mineral identical with olivine, composed of silicate of magnesia and iron, and crystallizing in the prismatic or orthorhombic system.

CHRYSOTILE : (χρυσός, gold; τίλος, hair). A fibrous variety of serpentine with a silky lustre, and frequently a yellow or green colour.

CILIOPODA : (*cilium*, an eyelash; πούς, a foot). A name proposed by Dr. Stoliczka for *Bryozoa*.

CLASS. In zoology, one of the great subdivisions of the animal kingdom, below the rank of subkingdoms. Rhizopods, sponges, corals, echinoderms, crustacea, insects, brachiopods, cephalopods, fishes and mammals are classes.

CLASTIC : (κλαστός, broken in pieces). Detrital: a general term applied to rocks formed from broken fragments of other rocks. The term is intended to include breccias, volcanic ash, and re-arranged detritus of all kinds, as well as ordinary sandstones, conglomerates, clays, &c.

CLAY IRONSTONE. A mixture of carbonate of iron and clay, found in beds and nodules, and especially common in the coal-measures.

CLAYSTONE. A term of somewhat loose application, generally used for compact felspar, felsite, or very felspathic igneous rocks. The term is also applied to disintegrated felsite, and sometimes, but rarely, to a sedimentary rock composed of hardened clay.

CLEAVAGE. A fissile structure, not due to the original bedding of a rock, nor, as a rule, coincident with it. Cleavage is characteristic of true slates, and has been shewn to be due to pressure exercised at right angles to the cleavage planes.

COAL. Vegetable tissue, converted into a substance proportionally poorer in water and volatile ingredients, and richer in carbon. Lignite has undergone less change than coal, but the two pass into each other.

CŒLENTERATA : (κοῖλος, hollow; ἔντερα, viscera). A group of animals distinguished from the lower forms (*Infusoria* and *Protozoa*) by having a hollow digestive cavity. This group comprises the *Anthozoa* or *Actinozoa* and *Hydrozoa*, and, according to some naturalists, the Sponges.

COLOSSOCHELYS : (κολοσσός, gigantic statue; χελύς, tortoise). A gigantic genus of tortoise, found in Siwalik rocks.

COMPACT. Firm and close-grained: a term applied to rocks.

CONCHIFERA : (*concha*, a shell; *fero*, I bear). A name formerly used by some naturalists for *Lamellibranchiata*.

CONFORMABLE. Beds having their stratification planes perfectly parallel, and in which the lower has not been eroded before the deposition of the upper.

CONGLOMERATE: (*con*, together, and *glomero*, I collect). Rocks composed of rounded pebbles cemented together, or imbedded in a sandy argillaceous or calcareous matrix.

CONIFERÆ: (*conus*, a cone; *fero*, I bear). An order of gymnospermous exogens, including pine and fir trees and their allies, and largely developed in past epochs.

COPPER GLANCE. Native sulphide of copper, crystallizing in the prismatic or orthorhombic system, and known also as chalcocite, redruthite, and vitreous copper.

COPPER PYRITES. Sulphide of copper and iron, containing, when pure, 34·6 per cent. of copper, crystallizing in the pyramidal or tetragonal system.

COPROLITE: (κόπρος, dung). Petrified excrement.

CORAL: (κοράλλιον). A general term for the calcareous structures secreted by *Anthozoa* and *Hydrozoa*.

CORAL REEF. A shoal or low island formed by the growth of corals, and by the accumulation and consolidation of their debris. In many tropical seas, archipelagoes of great extent are entirely formed of coral reefs. These have been shewn to have been built upon submerged land, the reef-building coral animals, which can only live at certain moderate depths, having gradually built up the island as the base sank.

CORUNDUM: (*kárand*, Hindi). Pure alumina, crystallizing in the hexagonal system. Sapphire and ruby are forms of corundum, and emery is a granular variety, mixed with magnetite or hæmatite.

COSMOGONY: (κόσμος, world; γονή, origin). An hypothesis of the origin of the universe.

CRAG. The local name for the pliocene beds of Eastern England.

CRATER: (κρατήρ, a cup). The orifice of a volcano.

CRINOIDEA: (κρίνον, a lily; εἶδος, form). An order of *Echinodermata* consisting of a cup-like body, giving off a variable number of arms (usually five), and either supported on a jointed peduncle or sessile.

CROP: CROP OUT. To appear at the surface. See "*Outcrop*."

CRUSTACEA: (*crusta*, a shell). A class of arthropodous *Annulosa*, or articulated animals, including crabs, lobsters, cyprides, cirripeds, *Squillæ*, wood-lice, king-crabs, copepods, trilobites, &c.

CRYPTOGAMIA: (κρυπτός, concealed; γαμέω, I marry). One of the primary divisions of plants, in which flowers and cotyledonous seeds are wanting.

CRYSTAL: (κρύσταλλος, ice). A mineral or salt having regular polyhedral structure. All crystalline forms known are divided into six systems: the cubical or isometric; the pyramidal, dimetric, or tetragonal; the prismatic, trimetric, or orthorhombic; the hexagonal or rhombohedral; the monoclinic or oblique; and the triclinic or anorthic.

Ctenoid: (κτείς, a comb; εἶδος, form). An order of fishes in Agassiz' arrangement, distinguished by their scales being pectinated on the posterior margin.

Cubical. A system in crystallography in which all the three axes are equal and at right angles to each other.

Cycadeaceæ. A great subdivision or natural order of gymnospermous exogens, comprising a few living genera, as *Cycas* and *Zamia*, and numerous extinct forms.

Cycloid: (κύκλος, a ring; εἶδος, form). An order of fishes in Agassiz' arrangement, distinguished by having round smooth scales, with a simple margin.

Cyclopteris: (κύκλος, a ring; πτερίς, a fern). A genus of fossil ferns, distinguished by having more or less rounded leaflets, without a midrib, but with dichotomous veins, radiating from the base to the margin.

Cypris. A genus of bivalve entomostracous freshwater crustaceans, having two flattish valves, with elliptical outlines.

Debris: (*débris*, fragments or wreck). An accumulation of loose material derived from the waste of rocks.

Degradation. The wasting and wearing away of rocks by atmospheric or aqueous action.

Deinosauria. See "*Dinosauria.*"

Deinotherium. See "*Dinotherium.*"

Delta. The alluvial land near the mouth of a river. The name was originally given to the triangular tract near the mouth of the Nile, and was derived from the resemblance of this area in form to the Greek letter Δ.

Denudation: (*denudo*, I lay bare). The removal of the superficial crust of the earth by the agency of the atmosphere and water.

Deposit: (*depono*, I lay down). Any substance originally suspended or dissolved in water and precipitated therefrom.

Detritus: (*detero*, I rub off). Material removed by disintegration and other agencies from the surface of rocks.

Devonian. A subdivision of palæozoic formations, resting upon the silurian, and overlain by carboniferous. The name is derived from the county of Devon in England.

Diabase: (διάβασις, a passage). A compound of plagioclase felspar (oligoclase, labradorite, albite or anorthite), with pyroxene and some chlorite. The rock in its fresh state is dark-green; it is usually fine-grained or micro-crystalline, and is distinguished from dolerite by the presence of chlorite.

Diallage: (διαλλαγή, difference). A foliated form of pyroxene, usually of a green or greenish grey colour. The name is also applied to forms of the allied minerals, bronzite and hypersthene.

DIASPORE: (διασπείρω, I scatter). A hydrate of alumina, crystallizing in the prismatic system, and found in small scattered crystals associated with corundum.

DICOTYLEDONOUS: (δίς, twice; κοτυληδών, seed lobe). Exogenous: the great subdivision of phanerogamous or flowering plants, distinguished by having seeds with two or more lobes or cotyledons, leaves with divided veins, and wood, if any, arranged in concentric layers.

DICYNODON: (δίς, twice; κύων, a dog; ὀδούς, tooth). An extinct reptile with two canine-like teeth, found hitherto in South Africa and India only.

DIKE. See "*Dyke.*"

DILUVIUM: (Lat., a deluge). This term is used, as opposed to alluvium, to indicate deposits produced by extraordinary water action. It was thus applied to the drift gravels, boulder clays, and erratics attributed originally to a deluge; and although the name is now but little used by English geologists, it is still commonly applied by French and German writers in the sense of post-tertiary or pleistocene.

DIMETRIC: (δίς, twice; μέτρον, a measure). A name formerly used by Dana for the pyramidal system in crystallography, now called by him tetragonal.

DINOSAURIA: (δεινός, terrible; σαύρα, lizard). An extinct order of reptiles having marked affinities with birds. The order included, amongst other genera, *Iguanodon* and *Megalosaurus.*

DINOTHERIUM: (δεῖνος, terrible; θηρίον, a beast). A genus of proboscidian mammals, having a very different dentition from *Elephas* and *Mastodon.*

DIORITE: (διοράω, I distinguish). A rock, usually fine-grained, of a dark-green colour, and consisting of felspar (not orthoclase) and hornblende.

DIP. The angle at which a stratum slopes from the horizontal plane of the earth's surface.

DIPTERA: (δίς, twice; πτερόν, a wing). An order of insects, including flies and gnats, and distinguished by having only two wings.

DOAB: (*do*, two; *áb*, water: Persian). The area between two confluent rivers, and the confluence itself.

DOLERITE: (δόλος, a trick or deceit). A rock of volcanic origin, composed of labradorite and pyroxene, and distinguished from trachyte and its allies by the much larger proportion of bases to silica.

DOLOMITE: (named after Dolomieu). Magnesian limestone: a carbonate of lime and magnesia in equal proportions when pure.

DUNE: (Fr.) A sand-hill.

DYKE. Volcanic or plutonic rock, filling a crack in a pre-existing formation.

Echinodermata: (ἐχῖνος, a hedgehog; δέρμα, skin). A great class of invertebrate animals, including sea urchins, star-fishes, brittle-stars, feather-stars, sea-slugs (*Holuthuridea*), &c.

Edentata: (*e*, without; *dens*, a tooth). An order of mammalia in which the teeth are absent or deficient. The sloths, pangolins, anteaters, and armadillos belong to this order.

Efflorescence: (*effloresco*, I put forth flowers). A saline crust forming on the surface of the ground or on rocks.

Elvan. A Cornish term for a felsitic rock, occurring in dykes. For *Elvanite*, see "*Porphyry*."

Elytrum: (ἔλυτρον, a cover). The wing case of a beetle, being one of the anterior pair of wings which are modified into sheaths to cover the second pair.

Enaliosauria: (ἐνάλιος, marine; σαύρα, lizard). An extinct order of reptilia, fitted to live in the sea, and comprising *Ichthyosaurus*, *Plesiosaurus*, &c. It is now considered to include two distinct orders, the *Ichthyosauria* and *Plesiosauria*.

Encrinites. A genus of fossil crinoids. The term is often used for fossil crinoids generally.

Endogen: (ἔνδον, within; γίγνομαι, I am formed). Monocotyledonous flowering plants, such as grasses, palms, lilies, &c., with simple veined leaves, seeds with one cotyledon, and the wood, if any, not in concentric layers.

Entomostraca: (ἐντέμνω, I cut up; ὄστρακον, a shell). The lower crustacea, so called from the segments of their bodies being unconsolidated.

Eocene: (ἠώς, dawn; καινός, recent). The lowest great subdivision of tertiary strata.

Eolian: (*Eolus*, god of the winds). A term occasionally applied to wind-carried formations, such as blown sand.

Epidote: (ἐπίδοσις, increase). A mineral composed of silicate of alumina, iron and lime, crystallizing in the oblique system, and generally of a green colour.

Epistilbite: (ἐπί, upon; and στίλβη, lustre). A zeolite; a hydrated silicate of alumina and lime, with some soda, crystallizing in the oblique system.

Epoch. A period in geological time.

Erratic. A transported fragment of rock, at a distance from the original bed. The term has been especially applied to the blocks of stone scattered over the plains of Europe, and formerly supposed to have been transported by a deluge, or wave of translation, but now generally considered to have been carried by ice; hence the term "erratic" has become generally synonymous with an ice-borne boulder.

Escarpment. An inland cliff, usually produced by the outcrop of a hard stratum.

ESTHERIA. A genus of bivalve crustacea.

EUPHYLLITE: (εὖ, beautiful; φύλλον, a leaf). A mica-like mineral belonging to the margarophyllite section, and composed of hydrated silicates of alumina, lime, potash, and soda.

EXOGEN: (ἔξω, outside; γίγνομαι, I am formed). The same as "*dicotyledonous*."

EXUVIÆ: (Lat., cast clothes). Remains of animals, especially the shelly coverings of invertebrates.

FACIES: (Lat., the face). A term used to imply the general aspect or relations of a fauna or flora.

FALSE BEDDING. Oblique lamination; the arrangement of sand and other materials of which a bed is composed in laminæ not parallel with the planes of bedding. False bedding is especially common in beds of sandstone deposited by running water, as by a river, or by tidal currents in the sea.

FAMILY. In zoology and botany, a group of allied genera.

FAULT. A miner's term for any break in the continuity of a coal seam or mineral vein, however caused. In geology, the name is only applied where fracture of any rocks has taken place, accompanied by the shifting, either vertical or horizontal, of the opposite faces of the crack.

FAUNA (*Fauni*, rural deities). The whole collection of animals inhabiting a given area, or preserved in a particular bed or formation.

FELSPAR or FELDSPAR: (the latter spelling is correct, the word being derived from the German *feldspath*). A very important group of minerals, one or the other species being a principal constituent of almost all igneous rocks. Orthoclase, albite, oligoclase, and labradorite are felspars; all consist of double silicates of alumina and one or more alkalies or alkaline earths, and crystallize in the oblique or anorthic system.

FELSITE or FELSTONE. A rock of compact texture, usually pale coloured, but sometimes black or brown, weathering white, composed chiefly of felspar with some quartz. Felsite is the matrix of most porphyries.

FENESTELLA: (Lat., a little window). A genus of *Bryozoa* found in the palæozoic rocks.

FERRUGINOUS: (*ferrugo*, iron rust). Impregnated with iron oxide.

FIRECLAY. Clay capable of resisting great heat without fusing.

FLAG or FLAGSTONE. Hard laminated or fissile stone, especially hard sandstone in thin slabs.

FLINT. Silicious concretions, usually translucent and tolerably homogeneous, occurring in chalk or limestone.

FLORA: (the goddess of flowers). The whole collection of plants inhabiting a given area, or preserved in a particular bed, formation, group, or

Foliation. The arrangement in alternating laminæ of different minerals, as commonly occurs in gneiss and other metamorphic rocks.

Foraminifera : (*foramen*, a small opening; *fero*, I bear). A group of *Rhizopoda*, living in hollow perforated shells, frequently chambered. *Globigerina*, *Alveolites*, and *Nummulites* are examples.

Formation. An assemblage of rocks of similar origin, connected by mineral characters, by organic remains, or by being of the same geological age.

Fossil : (*fossilis*, dug out of the earth). Originally, this term applied to all mineral substances; now, it is restricted to organic remains, animal or vegetable, imbedded in rocks.

Freestone. A stone, usually a sandstone, easily cut and dressed.

Fucoid : (*fucus*, sea-weed). A sea-weed, or a similar plant.

Gabbro : (Ital.) A rock composed of labradorite and diallage or hypersthene (bronzite). It is frequently associated with serpentine.

Galena : (Lat.) Native sulphide of lead, crystallizing in the cubical system.

Ganoid : (γάνος, brightness; εἶδος, form). An order of fishes, distinguished for the most part by hard polished rhomboidal scales. Ganoids are far more common in the upper palæozoic and lower mesozoic formations than at present.

Garnet : (*granatus*, like a grain). A mineral, crystallizing in the isometric or cubical system, and composed of silicate of alumina and lime or iron; the alumina often replaced by sesquioxide of iron, and the lime by magnesia or some other oxide.

Gasteropoda : (γαστήρ, belly; πούς, foot). A class of mollusks, comprising ordinary univalves, whelks, cowries, cones, periwinkles, limpets, &c.

Gault. An argillaceous bed in the cretaceous formation between the upper and lower greensand.

Genus : (Lat., a race). A group of allied species.

Ghât : (Hindi). A landing-place, ford, or pass. This term "ghâts," originally applied to the passes through the mountain ranges that run parallel, or nearly so, to the coasts of the peninsula, has now been transferred to the ranges themselves.

Glacial epoch. A period of low temperature intervening between tertiary and recent times.

Glacier (French). A mass of ice moving slowly down the valleys and other depressions of snow-clad mountains, and formed by the accumulation and consolidation of snow.

Glauberite. Native anhydrous sulphate of lime and soda, crystallizing in the oblique system.

Glossopteris : (γλῶσσα, the tongue; πτερίς, a fern). A genus of simple leaved ferns, with reticulate venation and a distinct midrib, com-

mon in the Indian coal-bearing rocks of the Damúda period, and in Australian coal-measures, but rare elsewhere.

GNEISS: (a German miner's term). A highly foliated rock, composed of quartz, felspar, and mica in crystals. The mica is sometimes replaced by hornblende, and garnets or other minerals are imbedded. Gneiss passes by insensible gradations into granite.

GONIATITE: (γωνία, an angle). A genus of *Cephalopoda* allied to *Ammonites*, but distinguished by having the sutures in angulate zigzag lines.

GRANITE. A plutonic rock, rich in silica, and composed of felspar, quartz, and mica. The felspar is almost always orthoclase; a second felspar, usually oligoclase, being frequently present also. In some forms of granite the mica is absent (aplite or pegmatite).

GRAPHITE: (γράφω, I write). A form of carbon, occurring pure or mixed with more or less iron oxide in crystalline rocks.

GRAPTOLITES: (γράφω, I write; λίθος, a stone). A group of fossils, characteristic of the cambrian and silurian periods, composed of straight or curved rods, with denticulation corresponding to cells on one or both sides, and supposed to have been *Hydrozoa*, allied to the recent sertularian zoophytes.

GRAUWACKÉ. A German miner's term for the older argillo-arenaceous beds, and often employed at one time as a name for the transition series. The term is now obsolete.

GRAVEL. Loose pebbles, with or without sand.

GREEN-EARTH. A hydrous silicate of iron and potash, found chiefly in basalt and other eruptive rocks.

GREENSAND. The name of two important subdivisions of the cretaceous system in England—the upper and lower greensands.

GREENSTONE. A general name for igneous rocks, composed principally of felspar and hornblende. By some writers certain plutonic rocks containing augite are also called greenstones.

GREYWACKÉ. See "*Grauwacké*."

GRIT. A coarse sandstone, or, according to some writers, a sandstone in which the grains of quartz are angular. The term is applied somewhat loosely.

GROUP. An association of beds agreeing in mineral character, or varying amongst themselves in mineral character, but containing the same fossils. The terms "group" and "series" are frequently used by geologists as equivalent terms. In the present work, "series" is always understood as implying a more extended range of formations, and usually as comprising several "groups."

GYMNOSPERMS: (γυμνός, naked; σπέρμα, seed). Dicotyledonous flowering plants, with naked seeds composed of two or more cotyledons. Conifers and cycads are included.

GYPSUM: (γύψος, lime or chalk). Hydrated sulphate of lime, crystallizing in the oblique system.

GYROGONITES: (γυρός, round; γόνος, seed). The spiral seed vessels of *Characeæ*, found in freshwater beds.

HABITAT. The country, district, or kind of locality in which an animal or plant is found living in a wild state.

HÆMATITE: (αἷμα, blood). Native iron oxide in a massive form, either crystalline or amorphous. The crystalline variety, known as specular iron, crystallizes in the hexagonal system.

HEMIHEDRAL: (ἡμι, half; ἕδρα, side). Crystalline forms made from other regular solids by the obliteration of half of the bounding planes.

HEULANDITE: (named after Heuland, a mineralogist). A zeolitic mineral; a hydrous silicate of alumina and lime, crystallizing in the oblique or monoclinic system.

HEXAGONAL: (ἕξ, six; γωνία, angle). A system in crystallography in which four axes are present, three equal lateral axes meeting at angles of 60°, and the vertical axis at right angles to the others.

HIPPARION (ἱππάριων, diminutive of ἵππος, horse,) or HIPPOTHERIUM. A genus of mammals found in the later tertiaries, and closely allied to the horse, but distinguished by the lateral digits of the feet being better developed and furnished with hoofs.

HIPPURITES: (ἵππουρις, a horse-tail). A genus of cretaceous bivalves of very peculiar form, one valve being conical or shaped like a horn, the other resembling a lid.

HORNBLENDE. A silicate of various bases, usually lime, magnesia, or iron, or combinations of these with each other, part of the silica being often replaced by alumina. The crystallization is oblique. Hornblende is an important constituent of many igneous rocks, such as syenite, diorite, &c.

HORNSTONE. A variety of flint or chert, resembling horn in appearance.

HYDROZOA: (ὕδρα, a water dragon; ζῶον, an animal). A class of animals belonging to the subkingdom *Cœlenterata*, allied to the *Anthozoa*, and comprising the hydroid or sertularian polypes, most of the jelly-fishes (*Acalephæ*), and some other forms.

HYPERSTHENE: (ὑπέρ, very; σθένος, tough). A silicate of iron and magnesia, usually containing also some lime and alumina, closely allied to bronzite.

HYPOGENE: (ὑπό, below; γίγνομαι, I am made). A term proposed by Lyell for the metamorphosed sedimentary formations formerly known as primary. The term is intended to express the idea that the beds in question had been transformed from below.

ICHTHYOSAURUS: (ἰχθύς, fish; σαύρα, lizard). An extinct genus of reptiles inhabiting the sea, having no exo-skeleton, the limbs converted into paddles, a large head, short neck, and probably a tail like that

of *Cetacea*. The genus gives its name to the order *Ichthyosauria*, which abounded in the mesozoic epoch, and especially in jurassic times.

IGNEOUS: (*ignis*, fire). A term applied to all geological phenomena supposed to be due to the action of heat. Igneous rocks are such as are believed to have undergone fusion. Particular igneous rocks were formerly supposed to be characteristic of different geological epochs, and some geologists still believe in the distinction, which has, however, been entirely abandoned by all the best English writers.

ILMENITE: (named after Ilmen). Titaniferous iron ore; hæmatite, in which part of the iron is replaced by titanium.

INFRA: (Lat., below). Applied to strata, *infra* implies a lower position: thus Infra-Król (p. 600) is the name of a group inferior to the Król; Infra-Vindhyan implies beds underlying the Vindhyans.

INFUSORIA: (*in*, and *fundo*, I pour). A class of microscopic animals, named from their occurrence in vegetable infusions.

INNATE: (*in*, and *natus*, born). A term applied to certain igneous rocks, which have undergone transformation, without intrusion or other change of position. Such rocks are believed to have been found by simple fusion *in situ*.

INSECTA: (*inseco*, I cut in pieces). A class of the arthropodous subdivision of *Annulosa*, characterized in all perfect forms by the possession of three pairs of legs attached to the thorax, and in most cases by two pairs of wings.

INSECTIVORA: (*insectum*, an insect; *voro*, I devour). An order of mammalia, comprising moles, shrews, hedghogs, *Tupaiæ*, &c.

IN SITU: (Lat., in place). A term applied to a rock or fossil when still in the exact position in relation to the matrix or surrounding rocks in which it was formed or deposited.

INVERTEBRATA: (*in*, privative; *vertebra*, a joint). All animals except the

IRONSTONE. Any ore of iron; but generally the name is [illegible] for carbonates, especially the argillaceous carbonate of iron so common in the coal-measures, and generally known as "clay ironstone."

ISOMETRIC: (ἴσος, equal; μέτρον, a measure). Dana's name for the cubical system in crystallography.

ISOTHERMAL: (ἴσος, equal; θέρμη, heat). Equal in temperature: a name applied to lines and zones of equal temperature, for any given period, on the earth's surface.

JADE. A name applied to several hard compact minerals, resembling each other in being tough, translucent, and very homogeneous in texture. One form (nephrite) is a variety of amphibole, another (jadeite) is a silicate of alumina and soda.

JASPER. Impure opaque coloured quartz, often of a bright red colour, or striped red and black or white.

JET: (*gagates*, from Gagas, a place in Lycia). A variety of coal having a very low specific gravity, homogeneous texture, and resinous lustre.

JHÍL: (Hindi). A marsh or shallow lake.

JOINTS. Parallel fissures or planes dividing rocks into more or less regular masses.

JURASSIC: (from the Jura mountains.) A system of rocks belonging to the mesozoic period, comprising the lias and oolite, and intervening between the trias below and the cretaceous above. By some geologists, the lias is separated from the jurassic system, and the latter then corresponds with the oolitic series of English geologists.

KANKAR. See p. 381.

KAOLIN: (Chinese). Fine porcelain clay, derived from the decomposition of felspar.

KEUPER: (German). The upper subdivision of the triassic system.

KHÁDAR. See p. 403.

KHÁL: (Bengali). A tidal creek.

KIESERITE: (from Kieser, a proper name). Hydrous sulphate of magnesia, crystallizing in the prismatic system.

KNORRIA: (from Knorr, a proper name). A carboniferous genus of *Lycopodiaceæ*, founded on stems with projecting leaf-scars arranged in a spiral.

KUNKUR. See p. 381.

KUPFERSCHIEFER: (*kupfer*, copper; *schiefer*, slate). A subdivision of the permian system in Germany.

LABRADORITE: (from Labrador, the original locality). A kind of felspar composed of silica, alumina, lime, and soda, crystallizing in the anorthic or triclinic system, and forming a constituent of many igneous rocks, such as basalt and diabase. Labradorite, when in large crystals, is often distinguished by a peculiar play of colours on the surface.

LABYRINTHODON: (λαβύρινθος, a labyrinth; ὀδούς, a tooth). An extinct genus of *Amphibia*, named from the complicated foldings on the transverse sections of the teeth. From this genus the order *Labyrinthodonta* was named: it comprised salamandriform animals with a long tail, and existed in upper palæozoic and lower mesozoic times.

LACUSTRINE: (*lacus*, a lake). Of or belonging to a lake.

LAGOON: (*laguna*, Ital.) A shallow salt-water lake or inlet, nearly or entirely cut off from the sea.

LAMELLIBRANCHIATA: (*lamella*, a thin plate; βράγχια, gills). A class of *Mollusca*, comprising ordinary bivalve shells, such as oysters, mussels, cockles, &c.

LAMINATION: (*lamina*, a thin plate). The division of rocks into thin parallel layers.

LAPILLI: (*lapillus*, a little stone). The finer forms of volcanic ash.

LATERITE. See p. 349.

LAUMONITE or LAUMONTITE: (from Laumont, the name of the discoverer). A hydrous silicate of alumina and lime, crystallizing in the oblique system, and usually found in the cavities of basalt and similar rocks associated with zeolites.

LAURENTIAN. Some of the oldest rocks in Canada, of age anterior to the Cambrian, and named thus from the river St. Lawrence. From these rocks the fossil *Eozoon*, supposed to be the oldest form of life known, was first obtained. The nature of this fossil is, however, disputed, and by some naturalists its organic origin is doubted.

LAVA: (Ital.) The molten rock that flows from a volcano in eruption. Lavas have the same composition as intrusive volcanic rocks, and are divided into two great sections: (1) Doleritic or basic, consisting largely of pyroxene, and not containing more than 45 to 55 per cent. of silica; and (2) trachytic or acidic rocks, with 60 to 80 per cent. of silica, and composed mainly of felspar.

LEPIDOLITE: (λεπίς, scale). A kind of mica containing lithia.

LEUCITE: (λέυκός, white). A silicate of alumina and potash, crystallizing in the cubical or isometric system, and found in volcanic rocks.

LEUCOPYRITE: (λευκός, white; πυρίτης, pyrites). Arsenide of iron, crystallizing in the prismatic system.

LIAS. The rocks at the base of the jurassic or oolitic system, classed by some with that system, by others as a distinct formation, intermediate between the oolites and the trias.

LIGNITE: (*lignum*, wood). Fossil wood, carbonised and altered, but still containing a much larger proportion of volatile ingredients than true coal.

LIMESTONE. Indurated carbonate of lime.

LITTORAL: (*littus*, the shore). A term applied to deposits formed in shallow water close to the coast.

LOAM. A soil composed of clay and fine sand.

LOESS. A term applied to a very fine unstratified or imperfectly stratified formation, composed of clay, very fine sand, and some carbonate of lime, occurring in the Rhine valley. Similar beds of great thickness have been found in China and other parts of Central Asia, and shewn to have been probably formed of fine dust transported by the wind.

LYCOPODIACEÆ. A class of acrogenous cryptogamic plants comprising the living club-mosses and numerous fossil forms.

LYDIAN STONE. A black siliceous rock, either a kind of jasper, or an altered siliceous shale.

MAGNETITE: MAGNETIC IRON ORE. An ore of iron composed of one equivalent of sesquioxide and one of protoxide, or of three equivalents of iron and four of oxygen. It crystallizes in the isometric or cubical system, and is usually found in octohedra.

MAMMALIA: (*mamma*, breast). The highest class of *Vertebrata*, comprising all animals that suckle their young.

MARBLE. Properly this term is only applied to the finer and more crystalline forms of limestone. Commonly, however, all rocks capable of being polished are thus called.

MARL. Clay mixed with carbonate of lime, but not consolidated into hard rock. The term is sometimes erroneously applied to non-calcareous clays.

MASTODON: (μαστός, breast; ὀδούς, tooth). An extinct genus of *Proboscidea*, closely allied to the elephant, but distinguished by the form of the teeth, which bear a number of rounded protuberances on the surface.

MEGALOSAURUS: (μεγάλο-great; σαῦρος, lizard). A genus of *Dinosauria*, of great size, with curved sabre-shaped teeth.

MESOZOIC: (μέσος, middle; ζωή, life). All formations, from the trias to the cretaceous inclusive, belonging to the middle or intermediate period between the palæozoic and tertiary or cænozoic epochs.

METAMORPHIC ROCKS: (μετά, after; μορφή, form). Rocks which have undergone a change of structure and become crystalline. The term is especially applied to sedimentary formations, which, through the agency of heat or chemical action, have acquired crystalline structure.

MICA: (*mico*, I shine). A group of minerals, distinguished by being easily split into thin elastic plates, composed of silicates of alumina and various earths and alkalies, and largely developed in crystalline rocks.

MICA SCHIST. A metamorphic foliated rock composed of mica and quartz.

MICACEOUS IRON ORE. A variety of hæmatite occurring in scales like mica.

MIOCENE: (μείων, less; καινός, recent). The middle subdivision of tertiary formations, above the eocene, and below the pliocene.

MOLLUSCA: (*mollis*, soft). One of the primary divisions or subkingdoms of animals, comprising cuttle-fish and ordinary univalve and bivalve shells, or *Cephalopoda*, *Gasteropoda*, *Pteropoda*, and *Lamellibranchiata*.

MOLLUSCOIDA: (*mollusca*, and εἶδος, resemblance). A primary division or subkingdom made for certain classes formerly united with *Mollusca*, but considered distinct by many modern naturalists. These classes are *Ascidioida* or *Tunicata*, *Bryozoa* or *Polyzoa*, and *Brachiopoda*.

MONOCLINAL: (*μόνος*, single; *κλίνω*, I incline). A bend, curve, or angle in strata, where one portion of the stratification plane is horizontal and the other inclined.

MONOCLINIC: (*μόνος*, single; *κλίνω*, I incline). Dana's name for the oblique system in crystallography.

MONOCOTYLEDONOUS: (*μόνος*, single; *κοτυληδών*, seed lobe). Endogenous: the great subdivision of phanerogamous or flowering plants, distinguished by having seeds with one lobe or cotyledon, leaves with subparallel and generally simple veins, and the wood not in concentric layers.

MONOMETRIC: (*μόνος*, single; *μέτρον*, a measure). A name formerly used by Dana for the cubical system in crystallography.

MONSOONS: (a corruption of *mausim*, a season, Hindi). Seasons of the year distinguished by the prevalence of winds which blow in opposite directions at different periods.

MORAINE: (French, of Switzerland). The accumulation of angular fragments of rock at the termination and along the sides of glaciers. The rocks are brought down from the mountains traversed by the glacier, and deposited where the ice melts.

MOORUM: (Dakhani Hindustani). Decomposed rock of any kind. The term is commonly used for partially disintegrated basalt near the surface.

MUSCHELKALK: (German, *muschel*, a shell; *kalk*, limestone). The middle group of the triassic formation.

MUSCOVITE: (from muscovy-glass, an old name). Common mica or potash mica; one of the constituents of granite, gneiss, and mica schist, chiefly a silicate of alumina and potash, with some iron, magnesia, soda, &c., and crystallizing in the prismatic system.

NALA: (Hindi). A rivulet or brook, ditch, canal, ravine or valley. The term is especially applied to a watercourse or ravine.

NATROLITE: (*natron*, soda). A zeolitic mineral, crystallizing in the prismatic system, usually assuming acicular forms, and consisting of hydrous silicate of alumina and soda.

NAUTILUS: (*ναυτίλος*, a sailor). A genus of tetrabranchiate cephalopodous *Mollusca* with coiled chambered shells, allied to *Ammonites*, but distinguished by having simple sutures. Some species are still living.

NEOCOMIEN: (*Neocomum*, Neufchatel). The lower subdivision of the cretaceous system.

NEOGENE: (*νέος*, new; *γίγνομαι*, I am formed). A term used by German geologists for all tertiary beds of later age than eocene.

NEOZOIC: (*νέος*, new; *ζωή*, life). All formations from the trias upwards, including both mesozoic and cænozoic or tertiary. The term is used in contradistinction to palæozoic.

NEPTUNIAN: (*Neptunus*, god of the sea). The stratified or aqueous deposits are thus termed in contradistinction to plutonic or igneous.

NEW RED SANDSTONE. The sandstones, permian and trias, above the coal measures in the British Islands.

NODULE. An aggregation of a mineral, such as carbonate of lime or silica around a nucleus, or central point.

NOEGGERATHIA: (named after Nöggerath, a botanist). A genus of plants of somewhat doubtful affinity, found in palæozoic rocks. The original types are now referred to *Cycadeaceæ*, but it is uncertain how far the various forms referred to the genus are really congeneric.

NULLAH. See "*Nala*."

NUMMULITE: (*nummus*, a coin). A genus of *Foraminifera*, consisting of lenticular shells composed of chambers arranged in a spiral. Nummulites are so abundant in eocene beds as to be characteristic.

OBLIQUE. A system in crystallography in which the three axes are unequal, and whilst two of the axial intersections are rectangular, one is oblique.

OBSIDIAN. A lava that has cooled rapidly and is consequently vitreous, like glass or slag. The term is especially applied to vitreous acidic or trachytic lavas, composed mainly of felspar.

OCHRE. Clay, strongly coloured by oxide of iron.

OLD RED SANDSTONE. The sandstones, now referred to the Devonian period, underlying the coal measures of the British Islands.

OLIGOCENE: (ὀλίγος, little; καινός, recent). A term employed by many German geologists for a subdivision of the tertiary epoch corresponding to the lower miocene and uppermost eocene beds of English geologists.

OLIGOCLASE: (ὀλίγος, little; κλάω, I cleave). A species of felspar, chiefly a silicate of alumina and soda with some lime and potash, crystallizing in the anorthic or triclinic system, and commonly found in granite and other plutonic rocks.

OLIVINE. A tribasic silicate of magnesia and iron, usually of a greenish colour and translucent, crystallizing in the prismatic system. The transparent forms are known as chrysolite. Olivine is common in basalt, and usually occurs in imbedded grains of a dark yellowish green colour.

OOLITE: (ᾠόν, egg; λίθος, stone). Limestone composed of small rounded concretionary particles. From the prevalence of such limestones in the middle secondary rocks, the term 'oolite' has been applied to the system of beds underlying the cretaceous.

OPAL. An amorphous form of silica, having a resinous lustre. Precious opal has a peculiar play of colours.

OPERCULUM: (Lat., a little cover). A shelly or horny appendage to the foot in many gasteropodous *Mollusca*, serving to close the mouth of the shell.

OPHIDIA: (ὄφις, a snake). An order of reptiles comprising the snakes.

ORDER. In animals and plants, a group of inferior rank to a class: thus in the class *Mammalia* the orders are *Primates, Carnivora, Chiroptera, Ungulata*, &c.

ORGANIC REMAINS. Any recognisable parts or impressions of animals or vegetables in a fossil state.

ORIENTAL. A name applied by Mr. Wallace to one of the great zoological regions into which the surface of the earth is divided. The Oriental region, by many zoologists known as the Indian region, includes India, the Burmese and Malay countries, Southern China, Java, Sumatra, and Borneo, with the western half of the Malay archipelago.

ORTHOCERAS: (ὀρθός, straight; κέρας, a horn). A genus of cephalopodous *Mollusca* with a chambered shell allied to that of *Nautilus*, but straight, not spiral.

ORTHOCLASE: (ὀρθός, straight; κλάω, I cleave). Common felspar, essentially a silicate of alumina and potash, crystallizing in the oblique or monoclinic system, and forming an important ingredient of granite, gneiss, and many other rocks.

ORTHORHOMBIC: (ὀρθός, straight; ῥόμβος, a rhomb). Dana's name for the prismatic system in crystallography.

OSSIFEROUS: (*os*, a bone; *fero*, I bear). Bone-bearing: applied to beds yielding bones of *Vertebrata*.

OUTCROP. The edge of a bed, where it appears on the surface of the ground.

OUTLIER. A portion of a bed detached from the main area by denudation.

PACHYDERMATA: (παχύς, thick; δέρμα, skin). A mammalian order of Cuvier's, comprising elephants, hyraces, and certain ungulates.

PALÆARCTIC: (παλαιός, ancient; ἄρκτος, a bear, *ursa major*). The great zoological region comprising Europe, Africa north of the Sahara, and all Northern and Central Asia.

PALÆONTOLOGY: (παλαιός, ancient, ὤν, being, λόγος, discourse). The science of ancient forms of life.

PALÆOZOIC; (παλαιός, ancient; ζωή, life). The lowest great division of stratified rocks, comprising the permian, carboniferous, devonian, silurian, cambrian, and laurentian systems.

PEAT. A brown or black carbonaceous substance formed in marshes from vegetable tissue by a process of chemical change. In Western Europe peat is mainly derived from the growth and decay of a kind of moss.

PEGMATITE: (πῆγμα, anything fastened together). Usually, a binary granite, composed of quartz and felspar without mica. By some German geologists, the name is applied to a granite containing orthoclase, quartz, and white mica. The term *aplite* is given by German petrologists to the pegmatite of English writers.

PELAGIC, or PELAGIAN: (πέλαγος, the open sea). Formed, living or deposited in the deep sea. The term is used in opposition to littoral or estuarine.

PELECYPODA: (πέλεκυς, an axe; πούς, foot). A term used by some naturalists instead of *Lamellibranchiata*, *q. v.*

PERCHED BLOCKS. Fragments of rocks transported by glaciers and left isolated on slopes of hills.

PERIOD. A subdivision of geological time.

PERISSODACTYLA: (περισσός, uneven; δάκτυλος, toe). A subdivision of the *Ungulata* distinguished by having an odd number of digits, and comprising horses, rhinoceroses, tapirs, *Palæotheria*, &c.

PERMIAN. The highest subdivision of palæozoic rocks, resting upon the carboniferous, and overlaid by triassic beds. The name is derived from the district of Perm, in Russia.

PETROLEUM: (*petra*, rock; *oleum*, oil). Earth-oil; liquid hydrocarbons found oozing from rocks in places, or occupying cavities, and formed during the slow alteration of organic matter.

PETROLOGY: (πέτρος, rock; λόγος, discourse). The science treating of rocks, their structure and composition.

PETROSILEX. A synonym of felstone or felsite, sometimes applied also to hornstone.

PHANEROGAMIA: (φανερός, apparent; γαμέω, I marry). One of the primary divisions of plants, including all with flowers and cotyledonous seeds. All plants without flowers and with obscure reproductive organization are, on the other hand, classed as *Cryptogamia*.

PHLOGOPITE: (φλογωπός, fire-like, in allusion to its colour). A kind of mica consisting essentially of silicate of alumina and magnesia, usually of a red colour, and often occurring associated with serpentine or crystalline limestone.

PHONOLITE: (φωνή, sound; λίθος, stone). A felspathic volcanic rock, known also as clinkstone; a compact mass, usually of a greenish grey colour, with here and there cleavage surfaces of vitreous felspar. This rock is named from its ringing sharply when struck by a hammer.

PISCES: (Lat.). Fish: a class of the subkingdom *Vertebrata*.

PISOLITE: (*pisum*, a pea). A concretionary limestone similar to oolite, but of coarser texture, the concretions being larger.

PITCHSTONE. A vitreous, dark-coloured rock of igneous origin allied to obsidian, but less glassy, of resinous lustre, and frequently containing small crystals and grains of quartz, felspar, &c.

PLACOID: (πλάξ, a flat plate; εἶδος, form). An order of fishes with flat smooth integument. This order comprises the sharks and rays.

PLAGIOCLASE: (πλάγιος, oblique; κλάω, I cleave). A name proposed by Breithaupt for the group of triclinic felspars, albite, oligoclase, labradorite, and anorthite.

PLEISTOCENE[1]: (πλεῖστος, most; καινός, recent). Post-tertiary or post-pliocene.

PLESIOSAURUS: (πλησίος, near; σαύρα, lizard). An extinct genus of marine reptiles somewhat allied to *Ichthyosaurus*, having, in a similar manner, limbs converted into paddles, and occurring in mesozoic strata. The neck is usually produced and the head small.

PLIOCENE: (πλειών, more; καινός, recent). The uppermost great subdivision of tertiary strata.

PLUTONIC: (*Pluto*, god of Hades). Igneous rocks formed beneath the surface of the earth and not erupted.

POIKILITIC[2]: (ποικίλος, many coloured). A term proposed originally as an equivalent for the New Red Sandstone, comprising both permian and triassic beds. Subsequently the name was used in a more restricted sense, but it has recently been revived by Huxley with its original meaning. At present, when employed, it is generally understood to include both permian and trias.

POLYCYSTINA: (πολύς, many; κύστις, a bladder). The minute siliceous shells of *Radiolaria*.

POLYPE: (πολύς, many; πούς, foot). The animal of a hydrozoan or anthozoan (actinozoan); that is, of a hydroid zoophyte, sea-anemone, or coral.

POLYZOA: (πολύς, many; ζῶον, animal). A synonym of *Bryozoa*, q. v.

PORPHYRY: (πορφύρεος, purple). An igneous rock, composed of a compact finely crystalline mass, in which large crystals of felspar are imbedded. Occasionally other minerals, besides felspar, occur in large crystals, and the term is applied by some geologists to rocks in which any mineral is developed in conspicuous crystalline masses. A *porphyritic* granite, syenite, greenstone, &c., is a rock in which the felspar is in large distinct crystals. The term '*porphyrite*' has been introduced by German geologists for quartzless porphyries consisting of a felsitic base with crystals of felspar, hornblende, or mica; *porphyry* being considered essentially *quartz porphyry* or

[1] This should be written '*plistocene*,' like pliocene.

[2] Correctly '*pœcilitic*.'

eloquite, a compact felsitic mass, with crystals of felspar and quartz.

PREHNITE: (named after the discoverer). A hydrous silicate of alumina and lime, crystallizing in the prismatic system, but usually occurring in reniform crystalline masses associated with zeolites.

PRIMARY: (*primus*, first). A term applied by the earlier geologists to the azoic rocks, and especially to the crystalline formations, granite, gneiss, &c. The name is still occasionally used as synonymous with palæozoic, q. v. *Primitive* has been used in the same signification as primary.

PRIMATES. The highest order of *Mammalia*, including men and monkeys. By Linnæus a more extended meaning was given to the term.

PRISMATIC. A system in crystallography in which the three axes are unequal and all are at right angles to each other.

PROTOGINE: (πρῶτος first; γίγνομαι, I am formed). A granite containing talc or chlorite instead of mica.

PROTOZOA: (πρῶτος, first; ζῶον, an animal). The lowest subkingdom of animals, comprising *Gregarinida*, *Rhizopoda*, and *Radiolaria*. By most naturalists the sponges are also included.

PTEROPODA: (πτερόν, wing; πούς, foot). A class of *Mollusca* in which part of the foot is developed into wing-like processes, with which the animal swims. The *Pteropoda* are pelagic animals, living near the surface of the ocean.

PULMONATA, or PULMO-GASTEROPODA: (*pulmo*, lung). A class of *Mollusca*, distinguished from true *Gasteropoda* by intestinal and reproductive characters. It comprises snails, slugs, pond snails (*Lymnea*), &c., but not the operculate land shells, *Cyclostoma*, *Helicina*, &c., which are ordinary *Gasteropoda*.

PUMICE. A kind of volcanic froth, the mass of air bubbles from the surface of lava consolidated, and forming a spongy rock, allied to obsidian in composition, but so light as to float upon water.

PYRITE. Iron pyrites; bisulphide of iron, crystallizing in the cubical system.

PYRITES: (πυρίτης from πῦρ, fire). Several sulphides of metals are thus termed; iron pyrites (pyrite), copper pyrites (chalcopyrite), &c. The term used alone generally signifies pyrite.

PYROXENE: (πῦρ, fire; ξένος, a stranger. The name was given by Haüy under the impression that the mineral was not igneous, whereas it is, except felspar, the commonest volcanic mineral). Augite, *q. v.*

PYRAMIDAL. A system in crystallography in which all three axes are at right angles to each other, and two of the three are equal to each other, but not to the third.

QUADRUMANA: (*quatuor*, four; *manus*, hand). A suborder of *Primates*, comprising monkeys.

QUAQUAVERSAL: (*quaqua*, wheresoever; *verto*, I turn). Dipping on every side: applied to the strata which dip in all directions towards or from a common centre.

QUARTZ. Pure silica, crystallizing in the hexagonal system. The word is a German mining term.

QUARTZITE. A metamorphic rock composed entirely, or almost entirely, of silica.

QUARTZ-REEF. A vein of silica traversing other formations.

QUATERNARY. A term used by some geologists for post-tertiary and recent formations.

RACE. A subdivision of a species comprising individuals related by descent.

RADIATA: (*radius*, a spoke). Cuvier's name for one of the primary subdivisions of the animal kingdom. This subkingdom included the modern *Protozoa* and *Cœlenterata*, the *Echinodermata*, and the *Bryozoa*.

RADIOLARIA: (*radiolus*, dim. of *radius*). A class of *Protozoa*, the skeleton of which, when any is present, usually consists of silica. Shells of *Radiolaria* are commonly known as *Polycystina*.

RECENT. In geology, the present epoch; the period during which no important change has taken place in the plants and animals inhabiting the earth.

REH. See p. 413.

REPTILIA: (*repo*, I crawl). A class of *Vertebrata*, comprising, besides crocodiles, lizards, snakes and tortoises, the extinct orders of *Ichthyosauria* and *Plesiosauria*, (which are united by some naturalists into a single order *Enaliosauria*,) *Dicynodontia*, *Pterosauria*, and *Dinosauria*.

RHÆTIC. A group of beds formerly classed in England as lower lias, and in Southern Germany as upper trias, but now separated by many geologists as an intermediate formation, and named from the Rhæti, the ancient inhabitants of the Tyrol. This group is also known as the *Avicula contorta* zone, and in Southern Austria as Kössener-schichten.

RHIZOPODA: (ῥίζα, a root; πούς, a foot). A class of *Protozoa*, comprising the *Foraminifera* and many forms without shells, such as *Amœba*, all of very simple organization, and having the power of thrusting out portions of their body as processes of variable form called '*pseudopodia*.'

RHOMBOHEDRAL: (ῥόμβος, a rhomb; ἕδρα, a side). A name often used instead of hexagonal for the system in crystallography with four axes.

RHYOLITE: (ῥύομαι, I protect). A rock allied to trachyte and felsite in composition. A compact or vitreous matrix enclosing grains or crystals of felspar, mica or quartz. The proportion of silica is larger than in trachyte.

ROCHES MOUTONNÉES. Rocks that have been rounded off and polished by ice action.

ROCK. In geological writings, this word is understood to mean any mineral substance occurring in large masses. Sand and clay in large quantities form rocks, as well as limestone or granite.

ROCK SALT. Common salt occurring as a rock.

RODENTIA: (*rodo*, I gnaw). An order of mammals distinguished by having the anterior teeth in each jaw modified into powerful cutting weapons. Rodents comprise squirrels, rats, porcupines, hares, and a few other forms.

RUMINANTIA: (*rumino*, I ruminate). A subdivision of the mammalian order *Ungulata*, comprising all animals which chew the cud, such as oxen, sheep, antilopes, deer, and camels.

RUTILE: (*rutilus*, red). A mineral composed of titanic acid, crystallizing in the pyramidal system, and occurring, usually, in imbedded crystals, and not unfrequently in acicular forms traversing quartz, in granite, gneiss and other rocks.

SACCHAROID: (σάκχαρ, sugar; εἶδος, form). A granular structure resembling that of loaf-sugar.

SALIFEROUS OR SALIFERIAN: (*sal*, salt; *fero*, I bear). Salt-bearing: a term applied by some geologists as a distinctive name to the triassic system.

SANDSTONE. A rock composed of sand cemented together.

SAURIAN: (σαύρα, lizard). Reptiles, and especially fossil reptiles, akin to lizards.

SCARP. A steep face of rock bounding a bed.

SCHIST: (σχίζω, I cleave). A metamorphic rock, having a distinctly foliated structure.

SCHORL. The black opaque variety of tourmaline, common in metamorphic rocks.

SCOLECITE: (σκώληξ, a worm; in allusion to its behaviour before the blowpipe). A zeolitic mineral, occurring in acicular crystals, belonging to the oblique system, found chiefly in basaltic rocks, and consisting of hydrous silicate of alumina and lime.

SCORIÆ: (Lat., slag). The vesicular portions of a lava flow, or the equally vesicular fragments ejected from volcanoes during eruption. The term is sometimes used as synonymous with volcanic ash, which is, however, of more general application.

SEAM. A bed or stratum: a term often used for beds of coal.

SECONDARY. A term originally applied to the sedimentary fossiliferous rocks above the primary crystalline strata and below the later or tertiary beds, but subsequently restricted to the formations from the triassic to the cretaceous inclusive, and used as synonymous with mesozoic.

SECTION: (*seco*, I cut). A face of rocks exposed by nature or art, or represented in a drawing.

SEDIMENT. Earthy deposit from mechanical suspension in water.

SEDIMENTARY ROCKS. Rocks formed of sediment.

SENONIAN: (from *Senones*, the Latin name of a people whose chief town was Agendicum, now Sens). A subdivision of the cretaceous system in France, corresponding to the upper chalk of English geologists.

SERIES. A collection of beds comprising several groups, connected by stratigraphical relations or by similarity of organic remains. See "*Group*."

SERPENTINE. A mineral, usually of a greenish colour, consisting of hydrous silicate of magnesia; a rock composed of the mineral in a more or less pure state.

SHALE. A consolidated and well-laminated argillaceous rock.

SHINGLE. Loose pebbles, especially those on the sea-shore.

SILICA: (*silex*, a flint). Silicic acid, a compound of the element silicon and oxygen. Quartz is the same as silica.

SILICEOUS. Composed partly or wholly of silica or quartz.

SILT. Fine sediment from water, especially from rivers.

SILURIAN: (*Silures*, the ancient inhabitants of a part of Western England and Wales). A system or series of lower palæozoic rocks, above the Cambrian and below the Devonian.

SIRENIA: (σειρήν, a siren or mermaid). An order of marine mammals, including the dugong, manatee, and *Rhytina*.

SLATE. A fissile non-crystalline argillaceous rock, the planes of separation in which are not due to bedding, but to cleavage. This is the true geological definition; but the term is often applied to hardened shales, which are bedded, not cleaved, and to schists, which are crystalline.

SLICKENSIDES. A mining term applied to the smoothed and striated surfaces of a fissure along which movement or faulting has taken place.

SOAPSTONE. See "*Steatite*."

SPAR. A common term for mineral crystals.

SPECIES. All plants or animals which resemble each other so closely in all characters, that it is convenient to call them by one name, form a species. They are supposed to be in general more closely connected by descent than different species are; but this rule is not quite accurate or certain. The term was originally applied to all individuals supposed to be descended from one pair, or one parent stock; but the definition is no longer considered sufficient, as it is believed that different species are connected by descent, and that specific distinction is frequently a matter of convenience in classification.

SPINEL. A mineral composed essentially of alumina and magnesia, the magnesia being sometimes replaced by lime or iron protoxide. Spinel crystallizes in the cubical system, and generally occurs in octohedra.

SPONGIDA, or SPONGIOZOA: (σπογγιά, a sponge). Sponges: a class of animals referred by most writers to *Protozoa*, but lately by some naturalists to *Cœlenterata*, and considered by others a distinct subkingdom.

SPORE: (σπορά, seed). The reproductive germ of a cryptogamic plant.

STALACTITE: (σταλάσσω, I drop). Earthy matter forming icicle-like projections, and separated from solution in water, through the evaporation of the latter, whilst trickling down cliffs, or dropping from the roofs of caves. The material is commonly carbonate of lime, less frequently chalcedony or some other mineral.

STALAGMITE: (στάλαγμα, a drop). Projections from the floor of a cave, produced, in the same manner as stalactites from the roof, by the evaporation of water dropping from above, and depositing carbonate of lime or any other mineral from solution.

STEATITE, or SOAPSTONE: (στέαρ, fat). A form of talc; a massive soft mineral, having a waxy lustre and a greasy or soapy feel.

STILBITE: (στίλβη, lustre). A zeolitic mineral: a hydrous silicate of alumina and lime, crystallizing in the prismatic system, and occurring commonly in basaltic rocks.

STRATUM: pl. STRATA: (*stratus*, spread). A bed or layer of a sedimentary rock.

STRIKE. A line drawn along a bed at right angles to the dip, being the intersection between the plane formed by the bed and the earth's surface, if horizontal. The line of outcrop of any stratum on level ground.

SUBCRYSTALLINE. Imperfectly crystalline. The prefix *sub*, under, indicates that the word to which it is added is to be understood as employed in a minor or inferior degree.

SUB-HIMALAYAS. The low ranges, along the southern base of the Himalayas, composed of tertiary rocks. The term is also applied to the rocks forming the low ranges in question.

SUBMETAMORPHIC. Partially or imperfectly metamorphic. The term is applied to the transition rocks of India, which are sometimes highly crystalline, but more frequently unaltered.

SYENITE: (from Syene, in Egypt). A plutonic rock, composed of felspar, quartz, and hornblende, and only differing from granite by the substitution of hornblende for mica. This is the signification of the term as employed by English geologists; but by German writers the name is used for a rock composed of orthoclase felspar and hornblende, without quartz, and the quartziferous rock is called syenitic granite.

SYLVINE: (from *Silvius*, a proper name). Native chloride of potassium.

SYMPHYSIS: (σύμφυσις, a growing together). The union of two bones.

SYNCLINAL: (συν, together; κλίνω, I incline). The curvature of strata in a trough or valley like form, the convexity or salient angle being downward.

SYNCLINAL AXIS. A line drawn along the lowest portion of a synclinal curve.

SYSTEM. A term applied in geology to the whole series of beds representing a subdivision of geological time, as the cretaceous system or tertiary system.

TALC: (derivation uncertain; said to be from an Arabic word). A hydrous silicate of magnesia, rarely crystallizing in the prismatic system, more commonly occurring in foliated masses or granular, very soft, and with a pearly lustre. The massive form is known as steatite or soapstone.

TALUS. The loose detritus accumulated by falling from the face of a cliff, precipice or slope, and not rearranged by water.

TERAI. See p. 401.

TERTIARY. The third or upper great division of geological time, including all formations above the cretaceous and below the deposits of the glacial epoch. The name is synonymous with *Cænozoic*.

TETRAGONAL: (τετράγωνος, four-angled). Dana's name for the pyramidal or dimetric system in crystallography.

THOMSONITE: (named after Prof. Thomson). A zeolite, crystallizing in the prismatic system, and consisting of hydrous silicate of alumina, lime and soda. It usually occurs in radiated masses.

TIN-STONE. Oxide of tin, crystallizing in the pyramidal system.

TOURMALINE: (*turamali*, Cingalese). A mineral, crystallizing in the hexagonal system, and commonly occurring in six-sided prisms. It is of variable composition, containing silicic and boracic acid, with alumina and magnesia, iron, soda, potash, or other bases, as well as a small percentage of fluorine. It is common in metamorphic rocks, occurring most frequently in the form of *schorl*.

TRACHYTE: (τραχύς, rough). A volcanic rock, usually of a pale colour, and mainly composed of felspar; a rough mass, frequently with imbedded crystals of sanidine (glassy felspar, a variety of orthoclase). Some hornblende or augite and dark-coloured mica are also present in most trachytes.

TRANSITION: (*transeo*, I go over). The rocks forming a passage from the crystalline gneiss and schists to the fossiliferous sedimentary rocks.

TRAP: (*trappa*, a stair, Swedish; *treppe*, German). A name originally applied to tabular greenstone and basaltic rocks, from their frequently occurring in hills with step-like terraces on the sides. The term subsequently was used in a somewhat vague manner for

all igneous rocks not distinctly granitic. By some geologists the name is now disused; by others it is restricted to stratified lavas, whether basaltic or trachytic, and to intrusive dykes and masses of basalt, greenstone, trachyte, or similar rocks. The term is too generally used to be abandoned; and for the ancient bedded lavas, which cover so enormous an area in India, no term equally expressive exists.

TRAVERTINE: (*Tiburtinus*, from Tibur, near Rome). Calcareous tufa deposited from the water of springs holding lime in solution.

TREMOLITE: (from Tremola, in Switzerland). A variety of hornblende, of a pale and often white colour, usually in fibrous radiated aggregates, and composed of silicate of magnesia and lime.

TRIAS. The lowest subdivision of mesozoic strata, overlying the permian or uppermost palæozoic series. The name is derived from the three groups of which the series consists in Germany and elsewhere.

TRICLINIC: (τρις, thrice; κλίνω, I incline). A name of Dana's for the anorthic system in crystallography.

TRIMETRIC: (τρις, thrice; μέτρον, a measure). A name formerly employed by Dana for the prismatic system in crystallography, now called by him orthorhombic.

TRILOBITA: (τρις, thrice; λοβός, a lobe). A group of *Crustacea* only found in palæozoic rocks, and having some resemblance in general form to a woodlouse. The cephalic shield is longitudinally divided into three by sutures.

TUFA: (Ital.) Any porous vesicular rock. The term is generally restricted to calcareous deposits from springs.

TUFF. A volcanic formation composed of loose material, scoriæ, lapilli, &c., cemented together. The term is especially applied to subaqueous volcanic accumulations.

TUNICATA: (*tunica*, a garment). A synonym of *Ascidioida*: a class of *Molluscoida* without shells.

UNCONFORMABLE: UNCONFORMITY. Strata are unconformable to each other when the lower has suffered from denudation before the deposition of the upper, or, in a minor degree, when the upper overlaps the lower. As a general rule, the planes of deposition in unconformable strata are not parallel to each other, but there are exceptions for instance, the lower bed may have been partially denuded whilst still perfectly horizontal, and a second horizontal bed may be deposited on the denuded surface of the first, without the latter having been disturbed. In this case the bedding planes in both continue parallel, although the two are quite unconformable.

UNGULATA: (*ungula*, a hoof). An order comprising all herbivorous and hoofed mammals, except the *Proboscidea*. It includes the *Pachy-*

dermata and *Ruminantia* of Cuvier, with the exclusion of *Elephas* and *Hyrax*.

UNICLINAL: (*unus*, one; κλίνω, I incline). See "*Monoclinal*." The term '*uniclinal*' being of improper construction, has been generally abandoned for the synonym.

UNSTRATIFIED. Rocks which do not occur in layers or strata.

VARIETY. A subdivision of an animal or vegetable species founded on minor characters.

VEIN. In geology, a fissure filled with some mineral substance differing from that of the rock around.

VERMES: (Lat., worms). A Linnæan name for several classes of *Invertebrata*, including insects, mollusks, *Zoophyta*, &c. It is now sometimes used as a synonym of *Annelida*; sometimes of *Annuloida*. At p. 286, it is employed in the former signification.

VERTEBRATA: (*vertebra*, a joint, from *verto*, I turn). A primary division or subkingdom of animals comprising all provided with a spine or backbone composed of joints called *vertebræ*. Mammals, birds, reptiles, amphibians, and fishes constitute the subkingdom.

VOLCANIC: (*Vulcanus*, god of fire). Igneous action at the surface of the earth, in contradistinction to *plutonic* action, which takes place beneath the surface.

VOLCANIC ASH. See "*Ash*."

WACKÉ. A German mining term for a somewhat decomposed state of doleritic and greenstone rocks.

WHIN: WHINSTONE. A Scotch term for basalt or greenstone.

WOLLASTONITE: (named after Dr. Wollaston). Silicate of lime, crystallizing in the oblique system.

ZAMITES. A genus of fossil cycadeaceous plants allied to the existing *Zamia*.

ZECHSTEIN: (German, mine-stone). A German term for the upper subdivision of the permian series, corresponding to the magnesian limestone of England.

ZEOLITE: (ζέω, I boil). A group of minerals, hydrous silicates of alumina and various earths and alkalies, all characterized by intumescence before the blowpipe. Several of the species are common in amygdaloidal volcanic rocks, filling the cavities.

ZIRCON: (from *jargon*, an old term for the gem). Silicate of zirconia, crystallizing in the pyramidal system. Zircons are found in some crystalline rocks.

ZOOPHYTA: (ζῶον, an animal; φυτόν, a plant). A term applied to the animals of *Hydrozoa*, sea-anemones and corals, or to all typical sessile *Cœlenterata*, and sometimes to *Bryozoa*.

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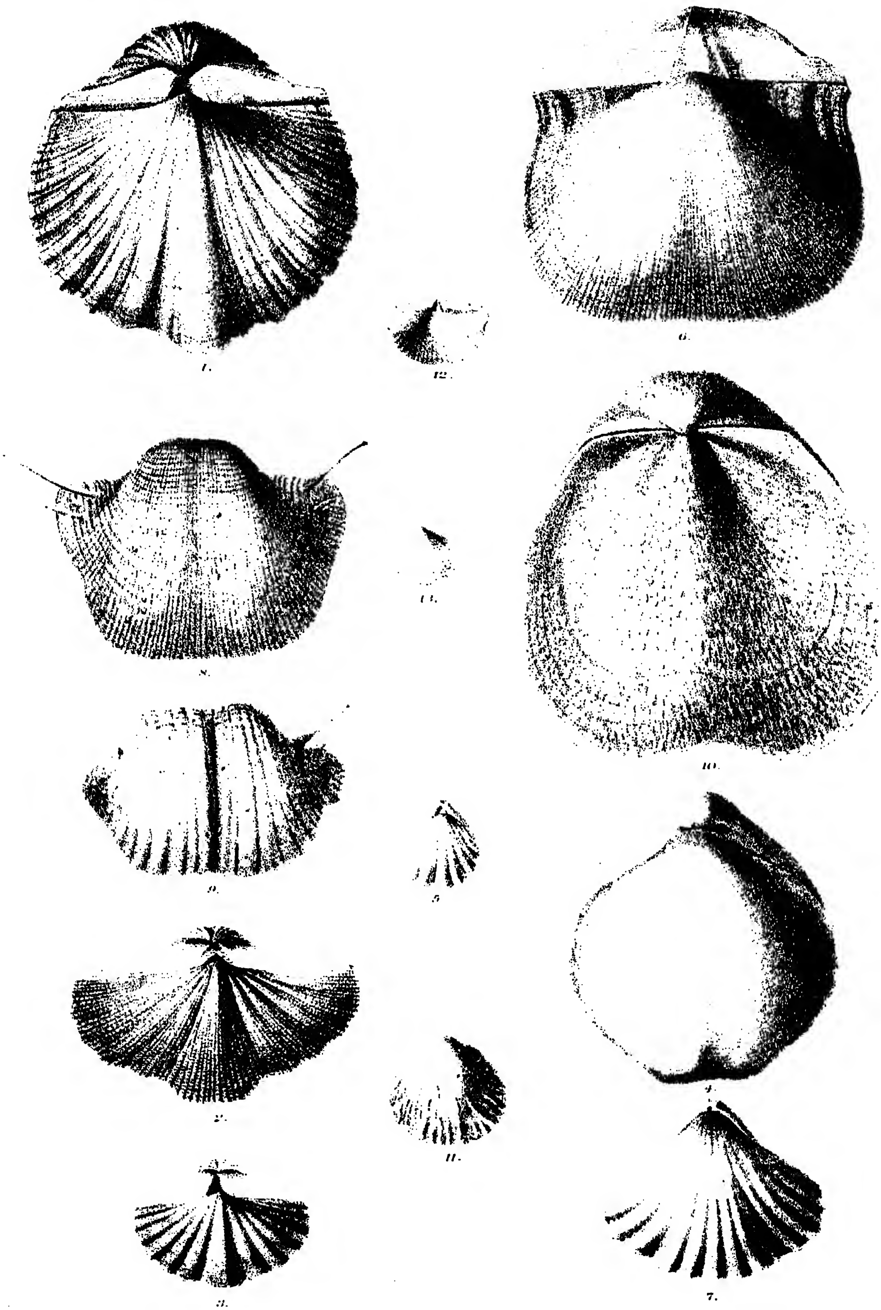
PLATE I.

CARBONIFEROUS FOSSILS (*Marine*).

Fig. 1. SPIRIFER KEILHAVII, Buch. (*S. rajah*, Salter.)
" 2. S. MOOSAKHAILENSIS, Davidson. Half natural size.
" 3. SPIRIFERINA OCTOPLICATA, Sowerby.
" 4. ATHYRIS SUBTILITA, Hall, var. *grandis*, Dav.
" 5. RETZIA RADIALIS, Phillips, var. *grandicosta*, Dav.
" 6. CAMEROPHORIA PURDONI, Dav.
" 7. STREPTORHYNCHUS CRENISTRIA, Phil.
" 8. PRODUCTUS SEMIRETICULATUS, Sow.
" 9. P. COSTATUS, Sow. Half natural size.
" 10. P. PURDONI, Dav.
" 11. STROPHALOSIA MORRISIANA, King.
" 12. CHONETES HARDRENSIS, var. *thibetensis*, Dav.
" 13. AVICULO-PECTEN HYEMALIS, Salter.

N. B.—All are of natural size, unless the proportions are mentioned.



J. Schaumburg. fecit

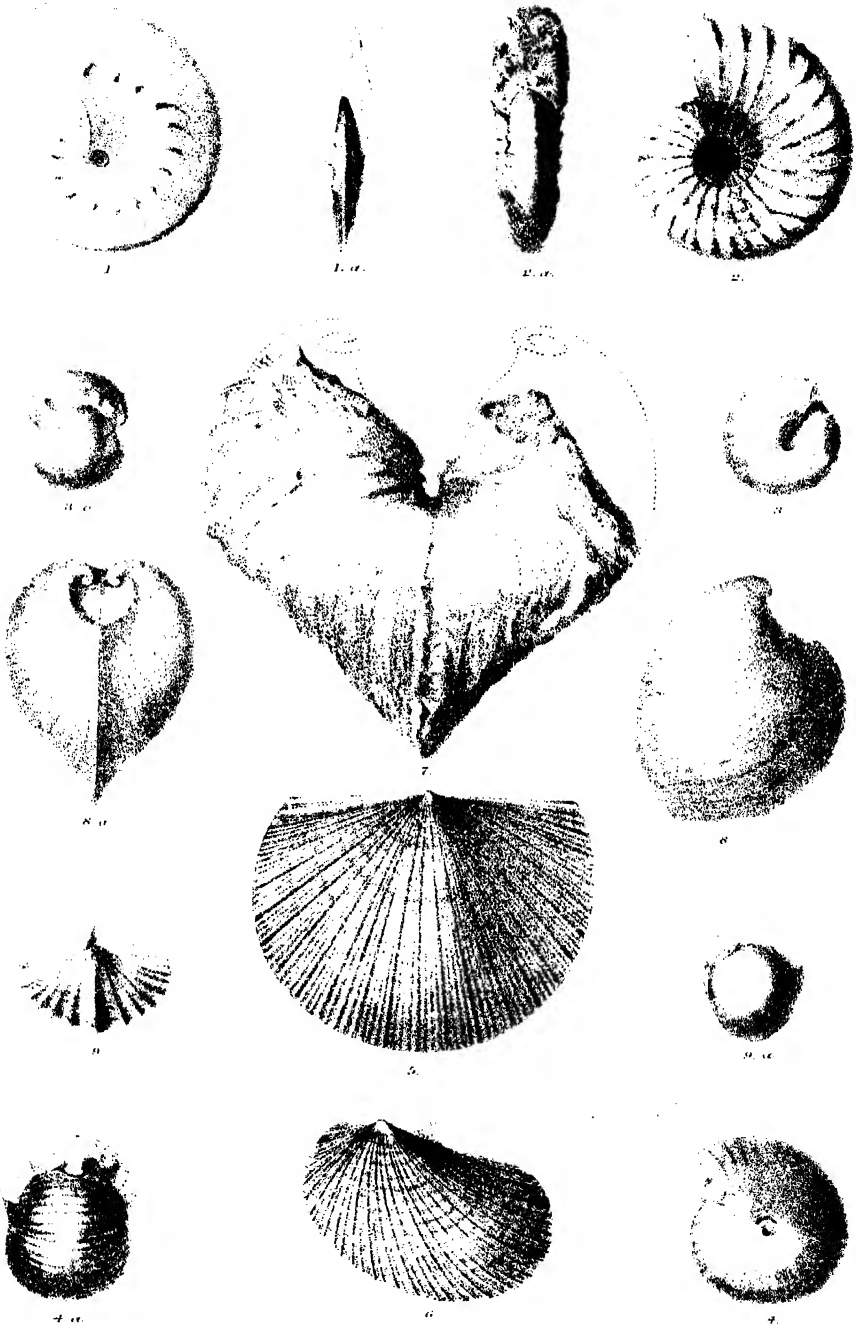
S. Sedgfield

CARBONIFEROUS FOSSILS.

PLATE II.

TRIASSIC FOSSILS (Marine).

Fig. 1. AMMONITES FLORIDUS, Wulfen. Half natural size.
„ 2. A. (CERATITES) THUILLIERI, Oppel. Half natural size.
„ 3. A. DIFFISUS, Hauer.
„ 4. CLYDONITES OLDHAMIANUS, Stoliczka.
„ 5. HALOBIA LOMMELI, Wissm.
„ 6. MONOTIS SALINARIA, Bronn. Half natural size.
„ 7. DICEROCARDIUM HIMALAYENSE, Stol. One-third natural size.
„ 8. MEGALODON TRIQUETER, Wulfen. Half natural size.
„ 9. SPIRIFER STRACHEYI, Salter.



TRIASSIC FOSSILS

PLATE III.

TÁLCHIR AND DAMÚDA FOSSIL PLANTS.

Fig. 1. GANGAMOPTERIS CYCLOPTEROIDES, Feistmantel.

„ 2 & 3. SPHENOPHYLLUM SPECIOSUM, Royle, sp. (*S. trizygia*, Unger).

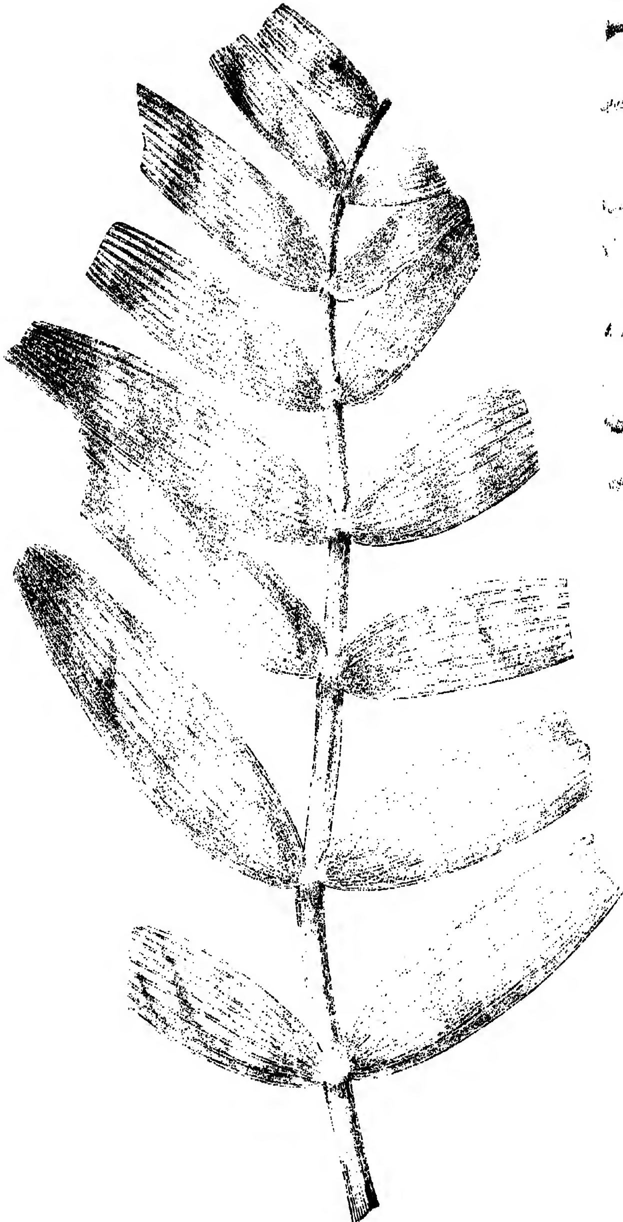
„ 4. PHYLLOTHECA INDICA, Bunbury.

PLATE IV.

DAMÚDA FOSSIL PLANTS.

Fig. 1 & 3. SCHIZONEURA GONDWANENSIS, Fstm.

„ 2. VERTEBRARIA INDICA, Royle.



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DAMUDA SERIES.

PLATE V.

DAMÚDA FOSSIL PLANTS.

Fig. 1, 2 & 3. PHYLLOTHECA INDICA, Bunbury. Leaves.

" 4. GLOSSOPTERIS INDICA, Schimper.

" 5. G. RETIFERA, Fstm. sp., nov.

" 6. G. ANGUSTIFOLIA, Brogniart.

PLATE VI.

KARHARBÁRI AND DAMÚDA FOSSIL PLANTS.

Fig. 1. VERTEBRARIA INDICA, Royle.

" 2. SPHENOPTERIS POLYMORPHA, Fstm.

" 3. TÆNIOPTERIS (*Macrotæniopteris*) DANÆOIDES, Royle, sp.

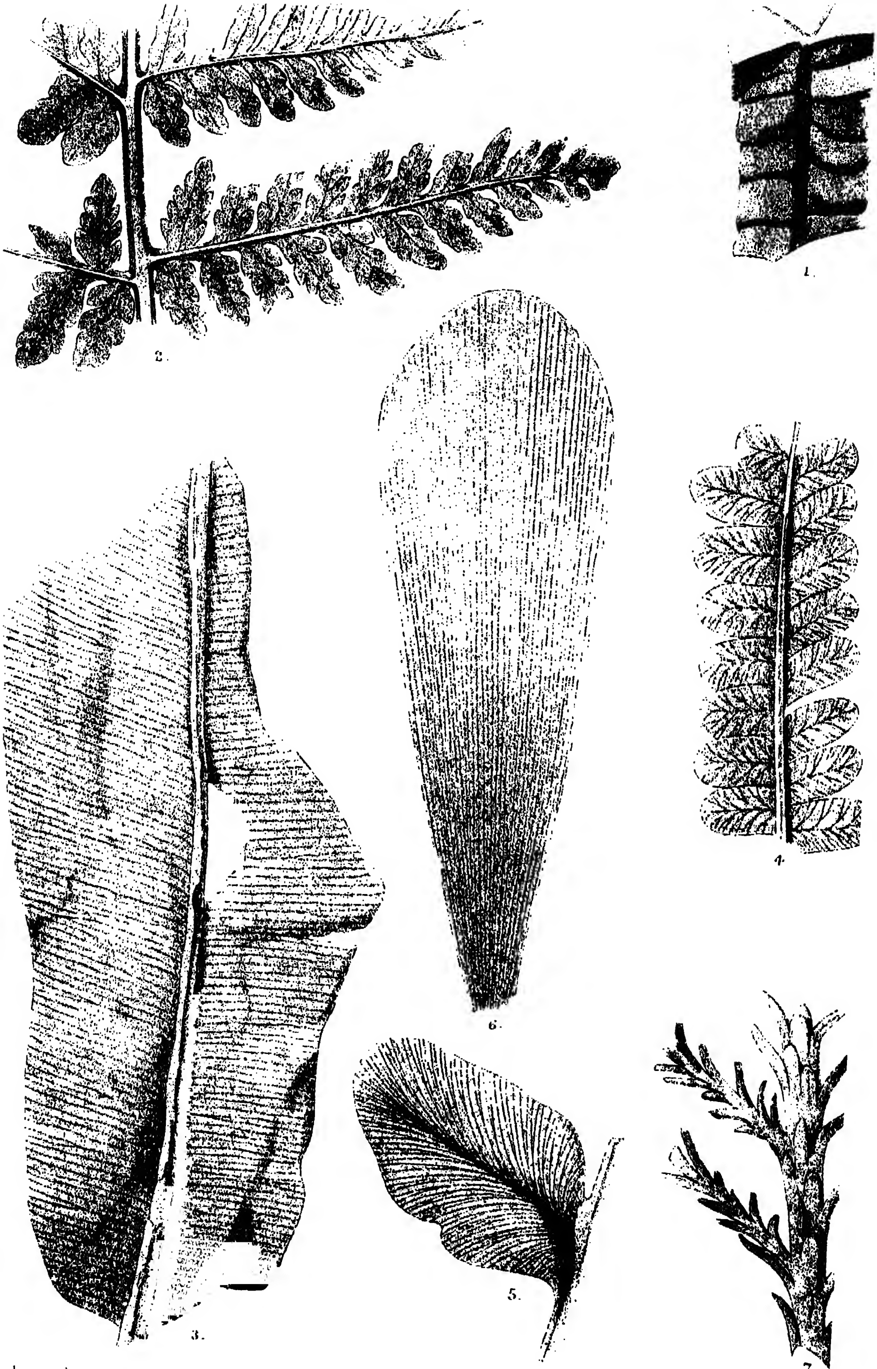
" 4. ALETHOPTERIS LINDLEYANA, Royle, sp.

" 5. NEUROPTERIS VALIDA, Fstm.

" 6. NOEGGERATHIA HISLOPI, Bunbury.

" 7. VOLTZIA HETEROPHYLLA, Bgt.

N. B.—Neuropteris valida and *Voltzia heterophylla* are Karharbári species, and should have been figured with the Tálchir *Gangamopteris cyclopteroides* on Plate III. The relations of the Karharbári group were not determined until after these plates were printed.



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DAMUDA SERIES

S. Sedgfield

PLATE VII.

PANCHET FOSSIL PLANTS.

Fig. 1, 2 & 3. **SCHIZONEURA GONDWANENSIS, Fstm.**

„ 4. **TÆNIOPTERIS (*Oleandridium*),** sp., allied to *O. stenoneuron*, Schenk.

„ 5. **CYCLOPTERIS PACHYRACHIS, Göppert.**

„ 6. **PECOPTERIS CONCINNA, Presl.**

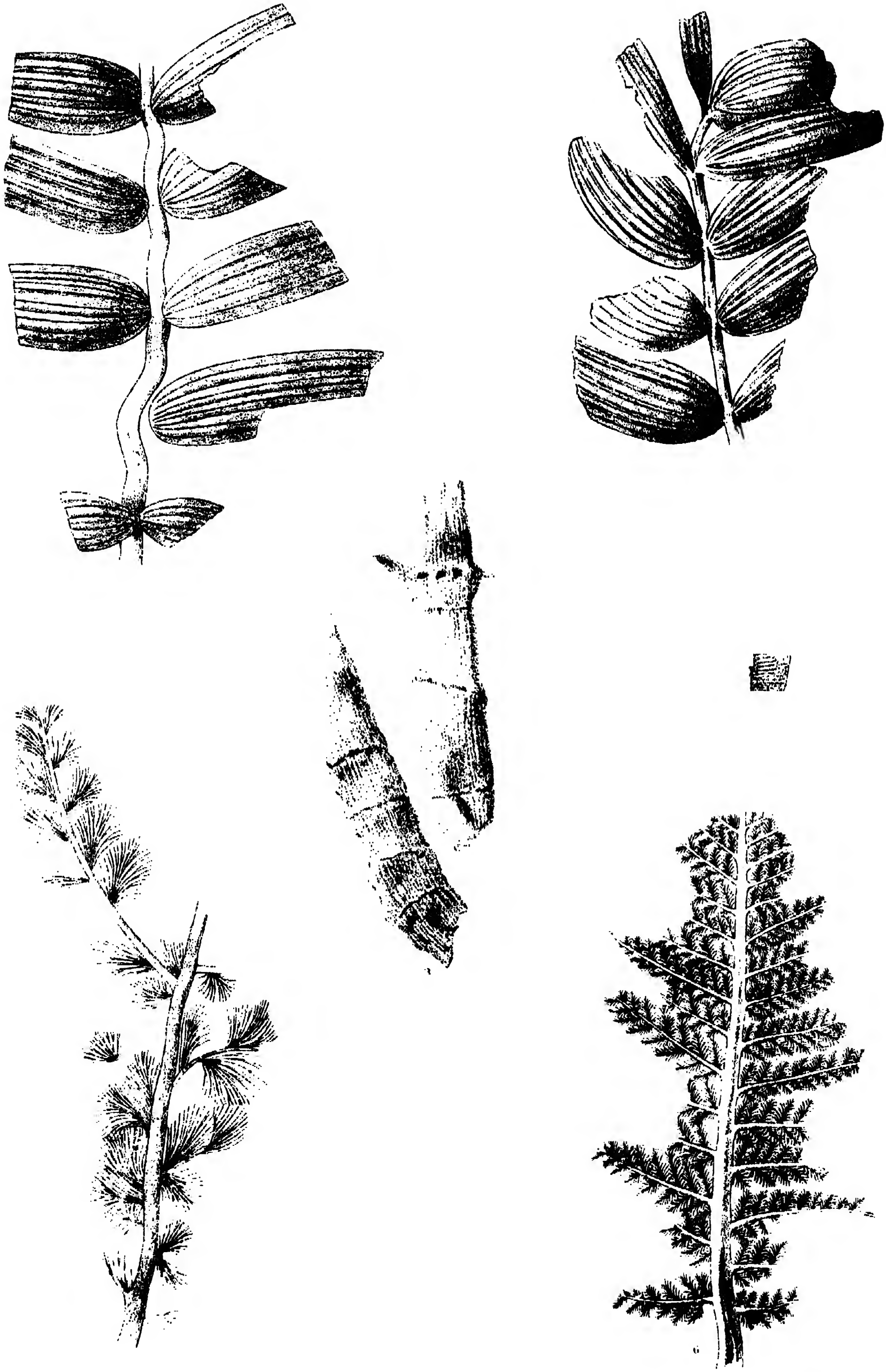

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PLATE VIII.

RÁJMAHÁL FOSSIL PLANTS.

Fig. 1. PTILOPHYLLUM ACUTIFOLIUM, Morris.

" 2. PTEROPHYLLUM RAJMAHALENSE, Morris.

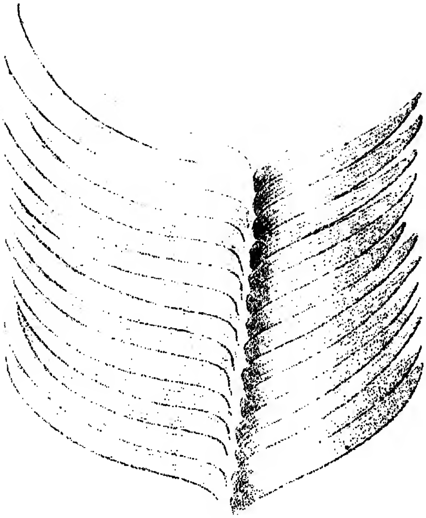
" 3. P. PRINCEPS, Oldham and Morris.

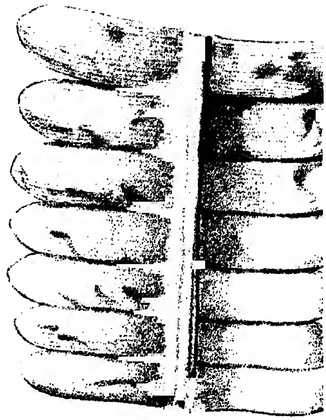
" 4. CYCADITES CONFERTUS, Morris.

" 5. OTOZAMITES BENGALENSIS, Oldham, sp.

" 6. DICTYOZAMITES FALCATUS, Morris, sp.

" 7. PALISSYA CONFERTA, Oldham, sp.





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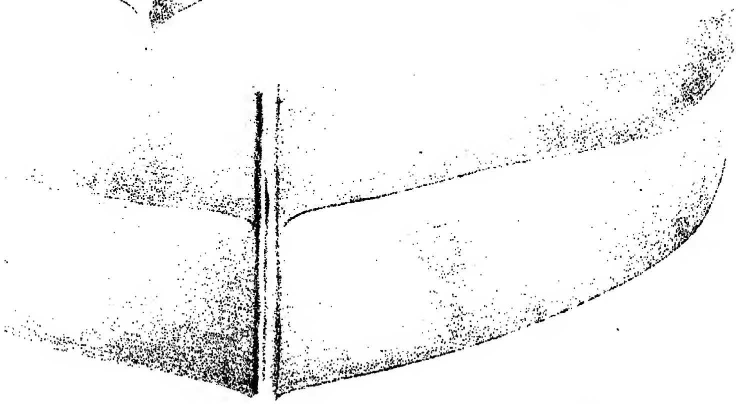

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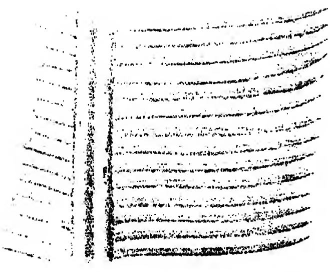

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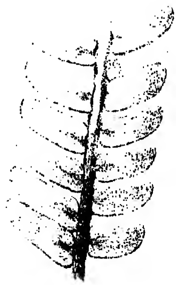

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PLATE IX.

RÁJMAHÁL FOSSIL PLANTS.

Fig. 1. GLEICHENIA BINDRABUNENSIS, Schimper; (*Pecopteris* [*Gleichenites*] *gleichenoides*, O. and M.)

" 2. ALETHOPTERIS INDICA, O. and M.

" 3. PECOPTERIS LOBATA, O. and M.

" 4. TÆNIOPTERIS (*Angiopteridium*) SPATHULATA, McClelland, sp.

" 5. T. (*Macrotæniopteris*) LATA, Oldham.

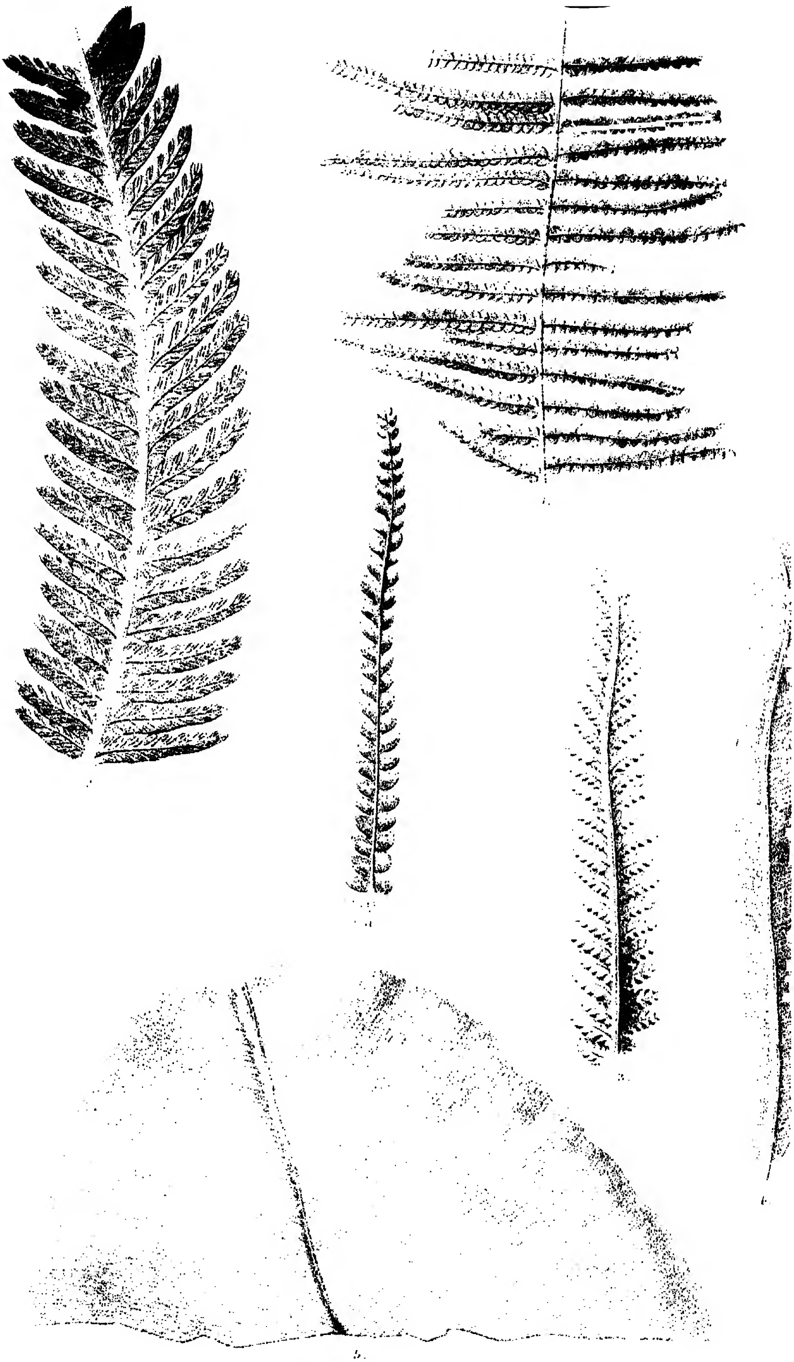
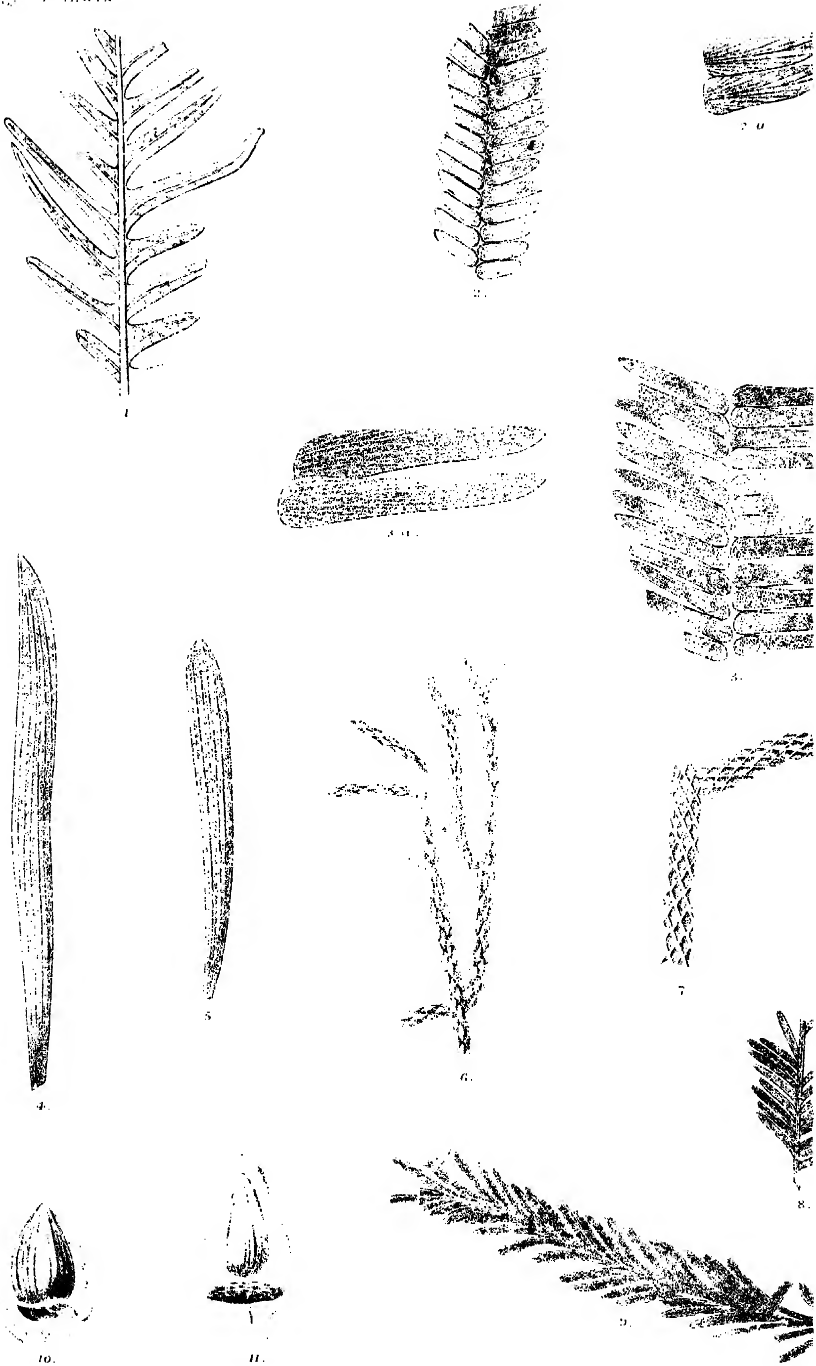


PLATE X.

JABALPUR FOSSIL PLANTS.

Fig.	1.	ALETHOPTERIS MEDLICOTTIANA, Oldham.
,,	2.	OTOZAMITES GRACILIS, Kurr, sp.
,,	3.	O. HISLOPI, Oldham.
,,	4 & 5.	PODOZAMITES LANCEOLATUS, Lindley and Hutton, sp.
,,	6 & 7.	BRACHYPHYLLUM MAMMILLARE, L. and H.
,,	8.	PALISSYA JABALPURENSIS, Fstm.
,,	9.	P. INDICA, Oldham, sp.
,,	10 & 11.	ARAUCARITES CUTCHENSIS, Fstm.



J. Schaumburg fecit

JABALPUR GROUP

PLATE XI.

UMIA (CUTCH) FOSSIL PLANTS.

Fig. 1. Tæniopteris (*Oleandr idium*) vittata, Bgt.

„ 2. Alethopteris whitbyensis, Bgt., sp.

„ 3 & 4. Ptilophyllum cutchense, Morris.

„ 5. Echinostrobus expansus, Sternberg, sp.

„ 6. Pachyphyllum divaricatum, Bunbury, sp.

„ 7 & 8. Araucarites cutchensis, Fstm.

PLATE XII.

JURASSIC FOSSILS (Marine).

Fig. 1. **Belemnites gerardi, Oppel. Half natural size.**

„ 2. **B. grantianus, D'Orbigny; (*B. kuntkotensis,* Waagen). Half natural size.**

„ 3. **Ammonites (*Phylloceras*) disputabilis, Zittel. Half natural size.**

„ 4. **A. (*Aspidoceras*) perarmatus, Sow. One-third natural size.**

„ 5. **A. (*Stephanoceras*) macrocephalus, Schlotheim. One-fourth natural size.**

„ 6. **A. (*Perisphinctes*) pottingeri, Sow. One-third natural size.**

„ 7. **Goniomya v-scripta, Agassiz. Half natural size.**

„ 8. **Pholadomya granosa, Sow. Half natural size.**

„ 9. **P. angulata, Sow. Half natural size.**

„ 10. **Trigonia clavellata, Lind. Half natural size.**

„ 11. **T. smeei, Sow. One-third natural size.**

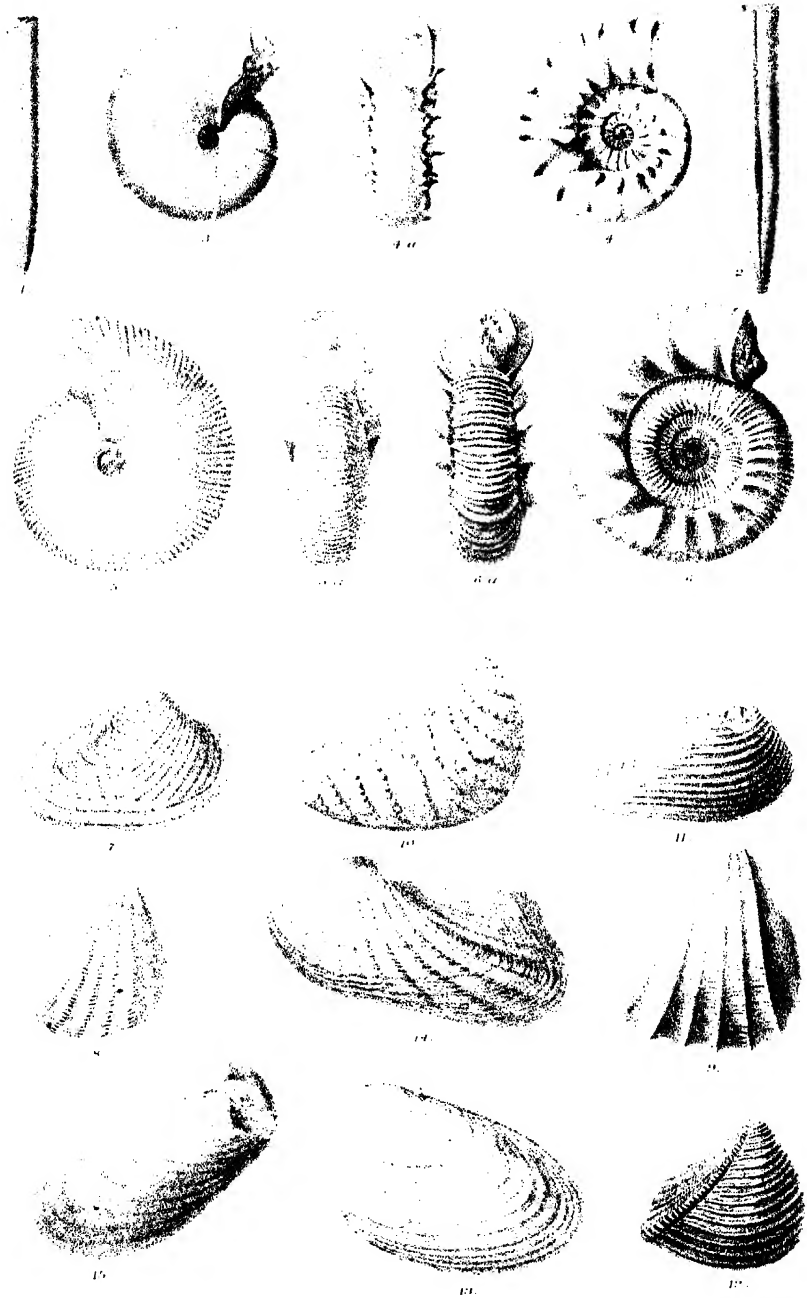
„ 12. **T. costata, Parkinson. Half natural size.**

„ 13. **Astarte major, Sow. One-third natural size.**

„ 14. **Arca (*Macrodon*) egertoniana, Stol.**

„ 15. **Aucella leguminosa, Stol.**

N. B.—Goniomya v-scripta **and** ***Trigonia clavellata*** **are not known to occur in India.**



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JURASSIC FOSSILS.

PLATE XIII.

CRETACEOUS FOSSILS (Marine).

Fig. 1. AMMONITES ROTOMAGENSIS, Defrance. One-third natural size.

„ 2. A. PLANULATUS, Sow. Half natural size.

„ 3. TURRILITES COSTATUS, Lamarck. Half natural size.

„ 4. BACULITES VAGINA, Forbes. Half natural size.

„ 5. APORRHAIS SECURIFERA, Forbes, sp.

„ 6. AVELLANA SCROBICULATA, Stol.

„ 7. CARDIUM (*Protocardium*) HILLANUM, Sow. Half natural size.

„ 8. TRIGONIA SCABRA, Lam.

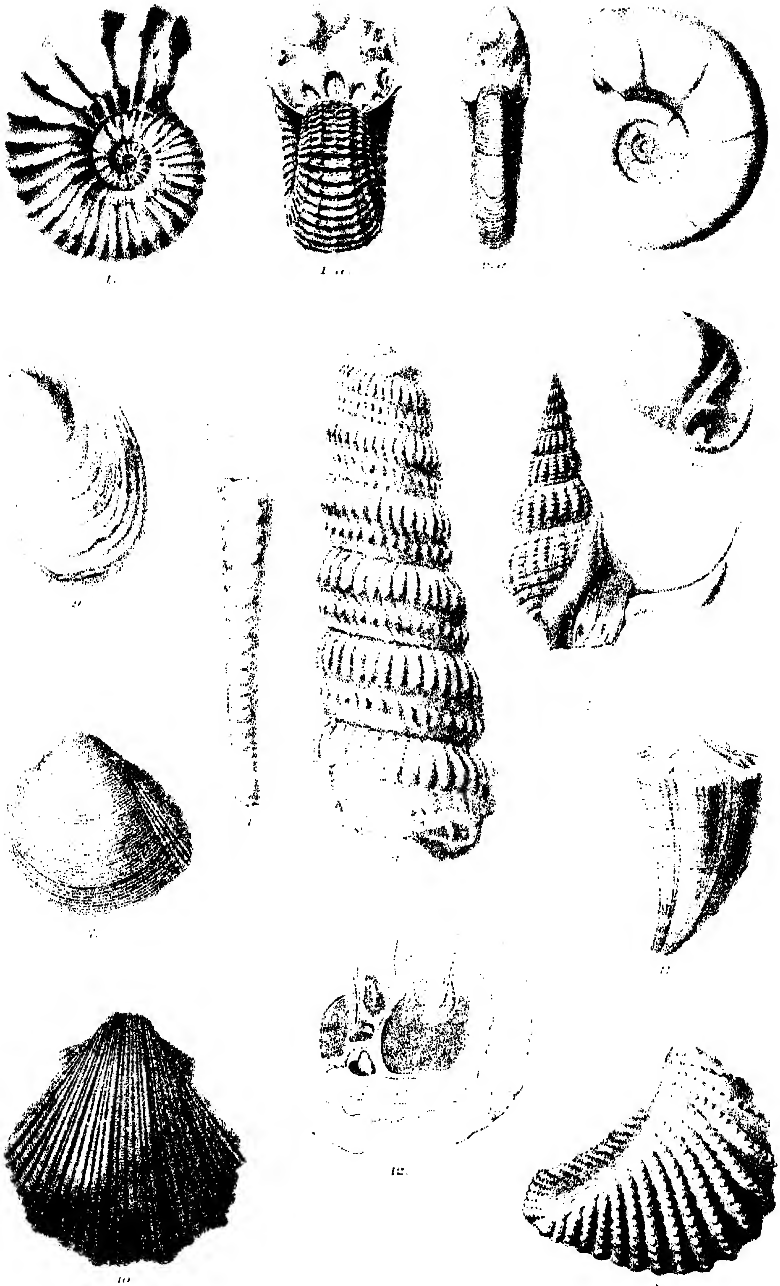
„ 9. INOCERAMUS SIMPLEX, Stol. Half natural size.

„ 10. PECTEN (*Vola*) QUINQUECOSTATUS, Sow.

„ 11. HIPPURITES ORGANISANS, Mont. One-fourth natural size.

„ 12. H. CORNU VACCINUM. Bronn. Transverse section; one-third natural size.

N. B.—The two species of *Hippurites* are not known to occur in India.



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CRETACEOUS FOSSILS.

PLATE XIV.

INTERTRAPPEAN FOSSILS (Upper cretaceous).

A.—Freshwater.

Fig. 1. PHYSA PRINSEPII, Sow. Normal form.
„ 2. P. PRINSEPII, Sow., var. *elongata*, Hislop.
„ 3. PALUDINA NORMALIS, Hisl.
„ 4. P. ACICULARIS, Hisl.
„ 5. P. SANKEYI, Hisl.
„ 6. P. DECCANENSIS, Sow.
„ 7. VALVATA MULTICARINATA, Hisl.
„ 8. VALVATA MINIMA, Hisl.
„ 9. LYMNEA SUBULATA, Sow.
„ 10. L. TELANKHEDIENSIS, Hisl., var. *peracuminata.*
„ 11. L. SPINA, Hisl.
„ 12. MELANIA QUADRILINEATA, Sow.
„ 13. UNIO DECCANENSIS, Sow. Half natural size.
„ 14. UNIO HUNTERI, Hisl. Three-fourths natural size.

B.—Estuarine.

Fig. 15. PSEUDOLIVA ELEGANS, Hisl.
„ 16. NATICA STODDARDI, Hisl.
„ 17. CERITHIUM STODDARDI. Hisl.
„ 18. VICARYA FUSIFORMIS, Hisl.
„ 19. TURRITELLA PRÆLONGA, Hisl.
„ 20. CARDITA VARIABILIS, Hisl.

PLATE XV.

EOCENE NUMMULITIC FOSSILS (Marine).

Fig. 1. VOLUTA JUGOSA, Sow.

" 2. NERITA SCHMIDELIANA, Chemnitz. 2 *a* : cast of the same.

" 3. PECTEN LABADYEI, D'Archiac and Haime.

" 4. VULSELLA LEGUMEN, D'Arch. and H.

" 5. ECHINOLAMPAS DISCOIDEUS, D'Arch. Half natural size.

" 6. EURHODIA MORRISI, D'Arch. and H.

" 7. ORBITOIDES PAPYRACEA, Boubée.

" 8. O. DISPANSA, Sow.; section. 8 *a*, *b*, *c*, *d* : varieties.

" 9. ALVEOLINA SPHEROIDEA, Lam. Enlarged three diameters. 9 *a* : the same; natural size. 9 *b* : transverse section.

" 10. NUMMULITES GARANSENSIS, Joly and Leymerie. 10 *a*, 10 *b* : sections of the same enlarged.

" 11. N. SUBLÆVIGATA, D'Arch. and H. 11 *a* : section of same.

" 12. N. RAMONDI, Defr.

" 13. N. OBTUSA, Sow.

" 14. N. GRANULOSA, D'Arch.

" 15. N. LEYMERIEI, D'Arch.

EOCENE (older tertiary) FOSSILS

PLATE XVI.

MIOCENE GÂJ FOSSILS (chiefly Marine).

Fig. 1. **VICARYA VERNEUILLI, D'Arch.**

„ 2. **TURRITELLA ANGULATA, Sow.**

„ 3. **OSTREA MULTICOSTATA, Deshayes.**

„ 4. **PECTEN FAVREI, D'Arch.**

„ 5. **ARCA (*Parallelepipedum*) KURRACHEENSIS, D'Arch.**

„ 6. **A. (*Anomalocardia*) LARKHANENSIS, D'Arch. (*estuarine*).**

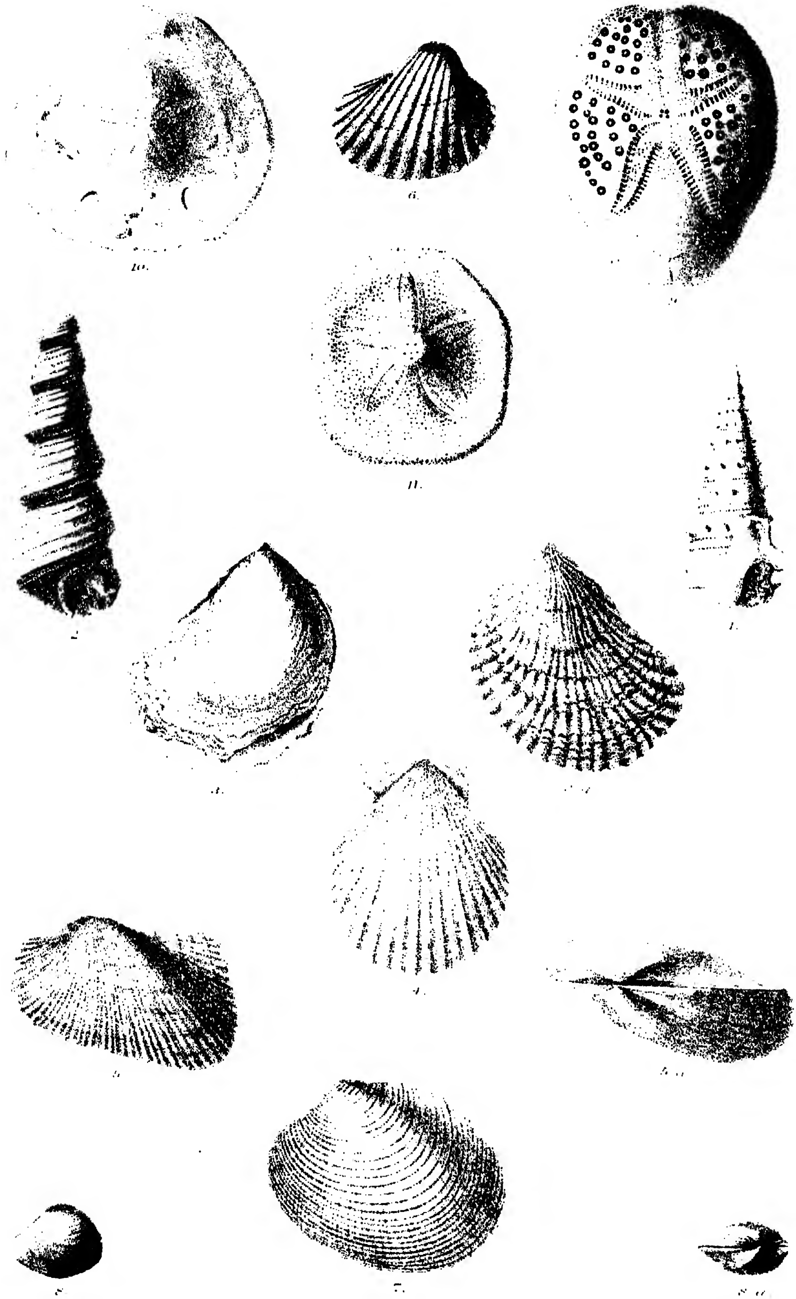
„ 7. **VENUS GRANOSA, Sow. Half natural size.**

„ 8. **CORBULA TRIGONALIS, Sow. (*estuarine.*)**

„ 9. **BREYNIA CARINATA, D'Arch. and H. Half natural size.**

„ 10. **ECHINODISCUS, sp.**

„ 11. **CLYPEASTER DEPRESSUS, Sow. Half natural size.**



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MIOCENE FOSSILS.

PLATE XVII.

***LATER TERTIARY FOSSIL MAMMALS** (chiefly Siwalik pliocene).*

Fig. 1. **Elephas** *(Stegodon)* **insignis, Falconer and Cautley. Restored cranium; one-twentieth natural size.**

„ 2. **E. *(Stegodon)* ganesa, F. and C. Restored cranium; one-twentieth natural size.**

„ 3. **Mastodon perimensis, F. and C. Restored cranium; one-twentieth natural size.**

„ 4. **Mastodon latidens, F. and C. Upper molar; one-third natural size.**

„ 5. **Elephas *(Euelephas)* hysudricus, F. and C. Lower molar; one-third natural size.**

„ 6. **Mastodon sivalensis, F. and C. Last upper molar; one-third natural size.**

„ 7. **Elephas *(Stegodon)* insignis, F. and C. Upper milk molar; one-third natural size.**

„ 8. **Hippohyus sivalensis, F. and C. Second upper molar.**

„ 9. **Sus giganteus, F. and C. Upper molars.**

„ 10. **Merycopotamus dissimilis, F. and C. Upper molar.**

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SIWALIK FOSSILS.

PLATE XVIII.

LATER TERTIARY FOSSIL MAMMALS (chiefly Siwalik pliocene).

Fig. 1. HEMIBOS TRIQUETRICERUS. F. and C. Cranium; one-sixth natural size.

„ 2. AMPHIBOS ACUTICORNIS, F. and C. Cranium; one-sixth natural size.

„ 3. DORCATHERIUM MAJUS, Lydekker. Upper molar.

„ 4. CHALICOTHERIUM SIVALENSE, F. and C. Upper molar; half natural size.

„ 5. BRAHMATHERIUM PERIMENSE, Falc. Upper molars; two-thirds natural size.

„ 6. HIPPOPOTAMUS (*Hexaprotodon*) SIVALENSIS, F. and C. Last upper molar; half natural size.

„ 7. SIVATHERIUM GIGANTEUM, F. and C. Restored cranium; one-eighteenth natural size.

„ 8. HIPPOPOTAMUS (*Hexaprotodon*) SIVALENSIS, F. and C. Cranium; one-eighth natural size.

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SIWALIK FOSSILS.

PLATE XIX.

LATER TERTIARY FOSSIL MAMMALS (chiefly Siwalik pliocene).

Fig. 1. RHINOCEROS SIVALENSIS, F. and C. Mandible; one-fourth natural size.

„ 2. R. IRAVADICUS, Lyd. Left upper molar; half natural size.

„ 3. R. SIVALENSIS, F. and C. Upper jaw, right side; one-fourth natural size.

„ 4. AMPHICYON PALÆINDICUS, Lyd. Upper molar (*miocene*).

„ 5. ENHYDRIODON SIVALENSIS, F. and C. Palate; four-ninths natural size.

„ 6. HIPPARION ANTELOPINUM, F. and C. Upper molar.

„ 7. LISTRIODON PENTEPOTAMIÆ, Falc., sp. Upper molar.

„ 8. HYÆNA SIVALENSIS, F. and C. Upper carnassial tooth.

„ 9. HYÆNARCTUS SIVALENSIS, F. and C. Right upper carnassial and molars; three-quarters natural size.

„ 10. HYÆNA SIVALENSIS, F. and C. Upper premolar.

„ 11. SEMNOPITHECUS ? SUBHIMALAYANUS, Meyer. Right upper molars.

„ 12. RHINOCEROS, sp. astragalus. One-fourth natural size.

J. Schaumburg, Lith:

SIWALIK FOSSILS

G. Sedgfield, imp.

PLATE XX.

POST-TERTIARY FOSSIL MAMMALS (*Narbada*).

Fig. 1. Bos (*Bubalus*) PALÆINDICUS, F. and C. Cranium; one-fifth natural size.

" 2. HIPPOPOTAMUS (*Hexaprotodon*) NAMADICUS, F. and C. Symphysis of mandible; one-eighth natural size.

" 3. Bos NAMADICUS, F. and C. Frontlet and part of right horn-core; one-tenth natural size.

" 4. EQUUS NAMADICUS, F. and C. Upper molars, right side; half natural size.

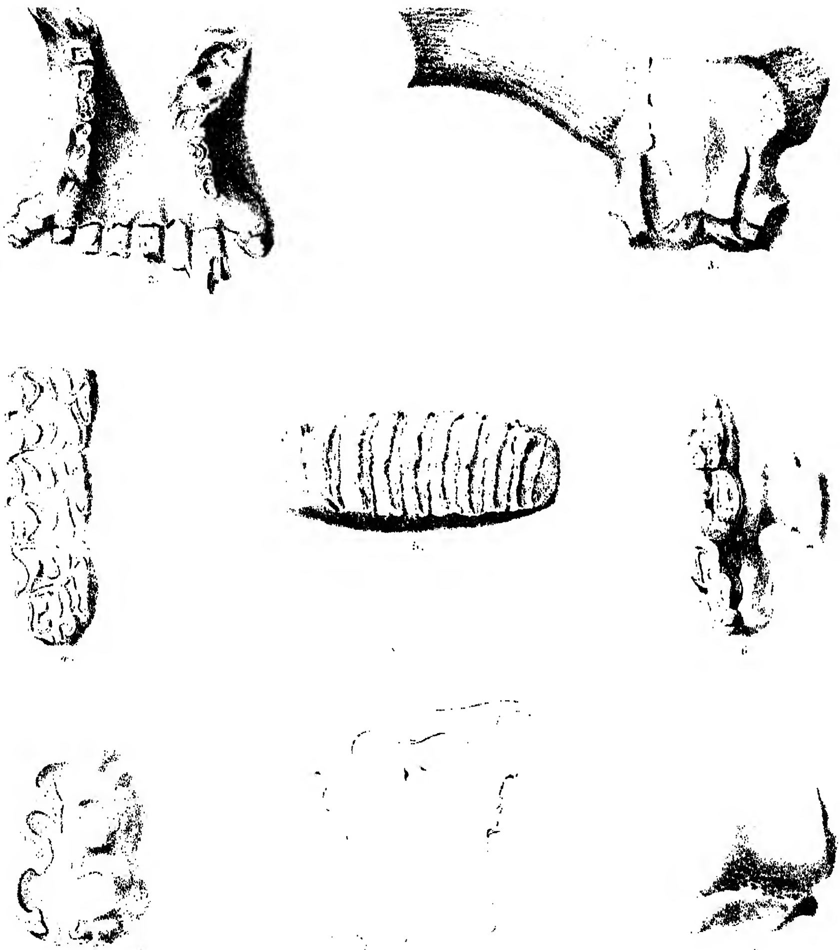
" 5. ELEPHAS NAMADICUS, F. and C. Lower milk-molar; one-third natural size.

" 6. URSUS NAMADICUS, F. and C. Part of upper jaw; half natural size.

" 7. HIPPOPOTAMUS (*Tetraprotodon*) PALÆINDICUS, F. and C. Last upper molar, left side; half natural size.

" 8. ELEPHAS NAMADICUS, F. and C. Restored cranium; half natural size.

" 9. RHINOCEROS NAMADICUS, F. and C., astragalus. One-fourth natural size.



NERBUDDA FOSSILS.

PLATE XXI.

STONE IMPLEMENTS (Post-tertiary and sub-recent).

Fig. 1. Chipped quartzite implement, 'spear-head' form, from the Narbada valley; two-thirds natural size. This specimen was found in the gravels which contain bones of extinct post-tertiary mammalia. See p. 386.

„ 2. Agate flake, or knife, from Godávari valley, natural size; also found in gravels containing bones of extinct post-tertiary mammalia. See p. 389.

„ 3. Chert core, found in the bed of the Indus at Sukker, natural size. See p. 442.

„ 4. Smoothed celt of greenstone from Banda, N. W. P.; natural size. See p. 442.

„ 5. Smooth and polished celt of limestone, adopted for a handle, from Burma; natural size. See p. 442.

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STONE IMPLEMENTS.